INDUSTRIAL RESEARCH

APRIL-MAY, 1961

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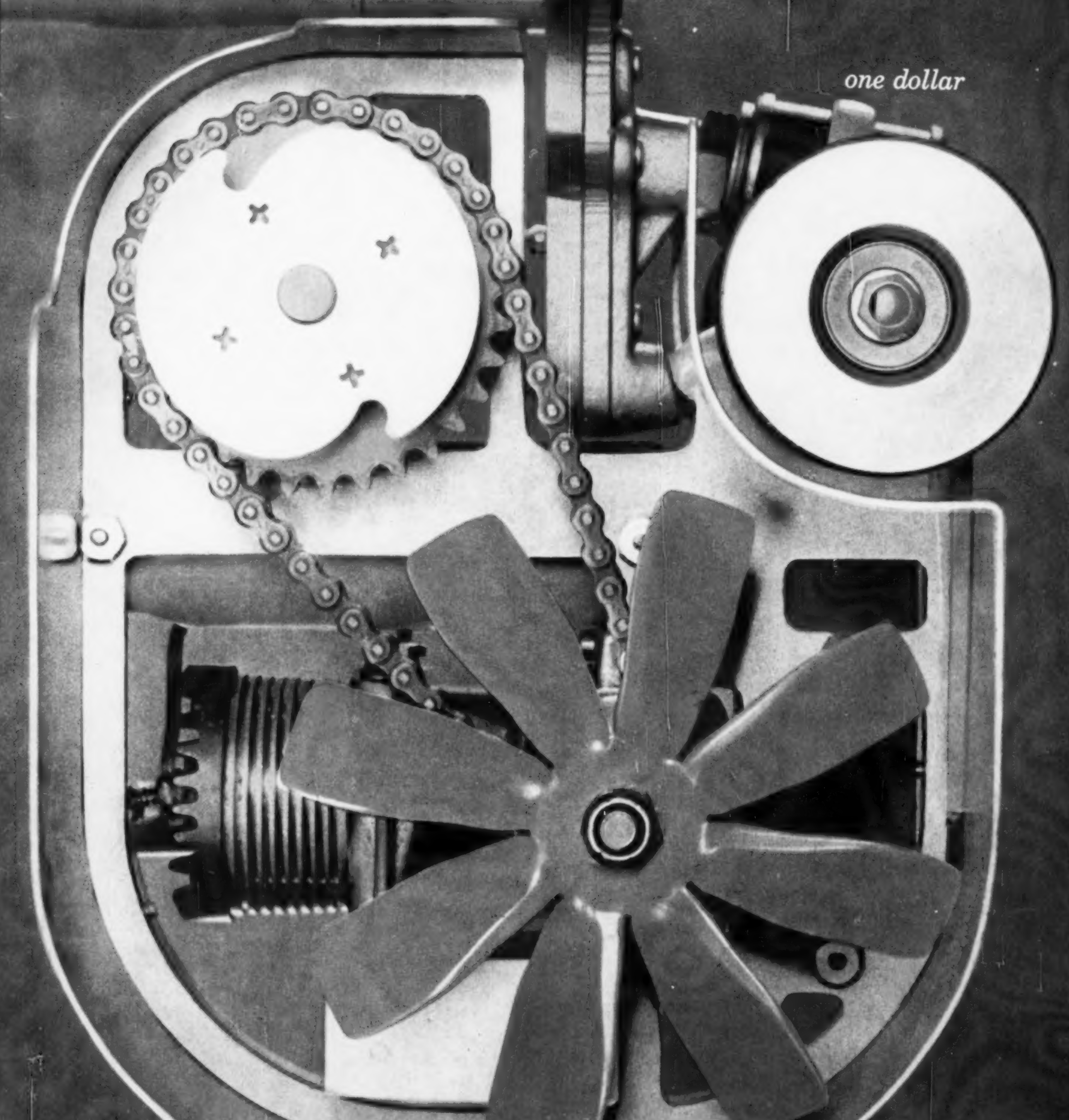

THE MAGAZINE FOR TECHNICAL MANAGEMENT

WHAT'S NEWS IN RUBBER

In design after design...the big switch is to BUTYL!

Automotive engineers have discovered that Enjay Butyl rubber is one of the best ways to improve car performance. Now all U.S. cars contain parts made from Enjay Butyl . . . parts such as weatherstripping, body mounts, engine mounts, radiator hose, accelerator pedals, and many more. Engineers specify Enjay Butyl rubber because...

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Enjay is always ready to help manufacturers build the extra performance of Butyl into their cars. For more information, contact Enjay's Detroit Area Office, 17360 West Eight Mile Road, Southfield, Mich. Phone KEnwood 2-7113.

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

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APRIL-MAY 1961 **RE**

THE COVER, *photograph of the one horsepower engine in the "Skeeter Scooter" designed by Illinois Tech graduate student Lou Richards, illustrates that new product ideas are pretty much where you find them—the point of Dr. Moore's article, "The Basic Approach to Product Development," beginning on page 20.*

Could you use a blueprint for planning a successful diversification program? One is offered in R. W. Race's article, "Why Diversify?" starting on page 53.

"The Quiet Revolution in Metalworking" (page 59) explains the new advances of manufacturing technology resulting from applied research. New methods, new hardware, and new ideas are transforming the plant complex into a single, efficient production tool.

I·R turns its special focus this issue toward the problem of how to retrieve the great mass of technical information, which has almost doubled since Sputnik. This issue's special section on Information Retrieval covers the problem from several viewpoints:

- *"Pitfalls of Information Retrieval" (page 33) explains the numerous systems for conducting literature searches that have been devised to prevent duplication of laboratory accomplishments.*
- *The important element of any information system—the user and his needs—is outlined in "Practical Information Handling" (page 41).*
- *The third article in the section, "Language Engineering" (page 44), introduces symbolic logic as a tool for the storage, searching, and translation of information for machine retrieval.*

The distinguished scientists who comprise the new I·R Editorial Advisory Board and some of their many accomplishments are presented on page 17.

Finally, a column, "Research Comment for Technical Management," has been added anew in this issue (page 67). The column is made up of interviews by Industrial Research editors with top management and leading scientists, along with excerpts from recent speeches and technical conferences you may have missed.

46,000 copies of this issue printed. Circulation audited and verified.

Industrial Research is dedicated to reducing the time lag between invention and production. It seeks to do this by informing technical management, creative engineers, and research workers of new scientific developments and their profitable applications in all fields of industry.

INDUSTRIAL RESEARCH

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Subscriptions: \$7 for one year (the next 12 issues; I•R will be monthly in October); \$12 for for two years; \$15 for three years, to United States, its possessions; \$2 extra for each 12 issues to foreign countries and Canada. Foreign remittance by International Money Order payable at Chicago, Ill., U.S.A. When changing address, please notify Circulation Dept. at address above. Notification of changes of job title are requested.

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Editorial: Professional science writers, industrial executives, research workers, educators, artists, and photographers are invited to query the editor at address above, with ideas for articles or art. Do not send manuscripts without query. Answers to queries are prompt.

INDUSTRIAL RESEARCH

APR-MAY 1961

THE MAGAZINE FOR TECHNICAL MANAGEMENT

(see page 73)

the 12th issue of I·R

12

INDUSTRIAL RESEARCH: *editorial, circulation, and advertising offices, 200 S. Michigan Av., Chicago 4, Ill. Vol. 3, No. 2, Apr-May, 1961, published bimonthly by Scientific Research Publishing Co. Inc. (Copyright © 1961). Copies of I·R on microfilm are available from University Microfilms, 313 N. First St., Ann Arbor, Mich. (See page 4 for subscription and other information.)*

ARTICLES

SPECIAL SECTION: INFORMATION RETRIEVAL

DEPARTMENTS

NEW FROM WESTINGHOUSE AT YOUNGWOOD

New Westinghouse High Gain Transistor simplifies circuitry, increases reliability, eliminates driver stage components, reduces cost of assembly.

NEW WESTINGHOUSE SILICON POWER TRANSISTOR PROVIDES GAIN OF

Westinghouse introduces a complete new family of High Gain Silicon Power Transistors providing a gain of 1000 or more at 2 amps . . . with guaranteed minimum gain of 400 at 10 amps (WX118X series) . . . a guaranteed minimum gain of 100 at 10 amps (WX118U series). These devices can substantially reduce circuit components, increase reliability, save space and weight.

They're ideal for application in high power, high efficiency regulators, amplifiers and switching circuits. For example, 1500 watts of power can be easily controlled with a 50 milliwatt signal! For full information call your nearest Westinghouse representative or write to Semiconductor Dept., Youngwood, Penna. You can be sure . . . if it's Westinghouse.

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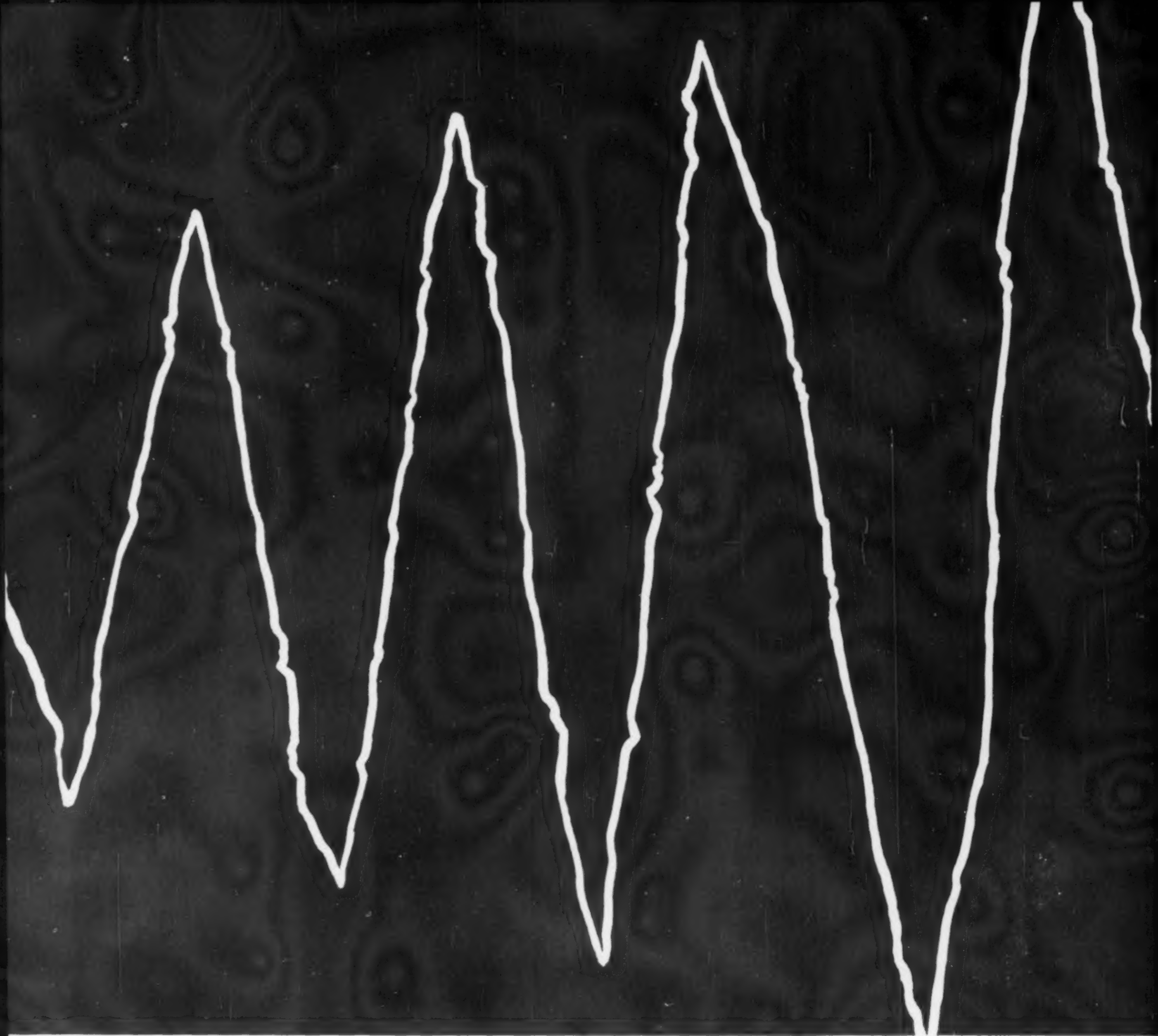

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Westinghouse

Diamonds machine ceramic parts

Diamonds polish dies for plastic dinnerware

EACH OF THESE JOBS IS NOW DONE BETTER AND CHEAPER WITH DIAMONDS

Other abrasives and cutting tools were once used to perform every job shown here. But it was found, in every case, that diamonds do the work better, last longer, are more economical than the old way.

These pictures prove the versatility of diamonds, too. Look at the different *kinds*

Diamonds remove bumps from concrete runways and highways

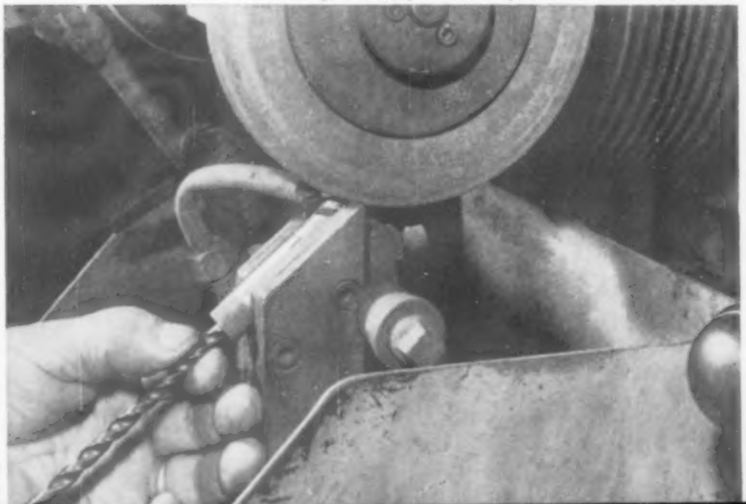
Diamonds edge automotive safety glass

of jobs they can do—everything from polishing the sensitively controlled dies that shape plastic dinnerware to shaving the bumps from a concrete jet runway.

If you cut, sharpen or smooth in your business, you can probably use diamonds to advantage. Next time you buy wheels or tools, ask for diamonds. Test them against the method you're now using. You'll find out how economical a diamond can be.

INDUSTRIAL DISTRIBUTORS (SALES), LTD., LONDON

Diamonds grind chip-control splits in crankshaft drill



INDUSTRIAL DIAMONDS
CUT PRACTICALLY EVERYTHING . . .
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Sliding contacts for printed circuits are plated with rhodium, over nickel, to obtain tarnish-free, hard surfaces for long and economical service life. (The illustration is rose-tinted . . . rhodium derived its name from its salts of this hue.)

CONTACT SURFACES OF PRINTED CIRCUIT SWITCHES...

Where any metal but Rhodium would cost too much...

Not so long ago, switch contact surfaces of printed circuits going into computers, guidance devices and advanced instrumentation wore out much too soon.

To Litton Industries, U.S. Engineering Co. Division, the problem was important and they soon came up with the answer. Investigation proved non-tarnishing rhodium, plated on nickel, was the metal for the job.

And it paid off! What started as an engineers' dilemma ended as an important contribution by Litton to printed circuit designing.

Rhodium proved easy and dependable to electroplate and the contact surfaces had the desired wear resistance. The rhodium-finished switch contact surfaces now give long life and reliable service. What's more, rhodium provides this superior performance for less than five cents per board.

A platinum metal may economically solve your problems

Where a hard surface, immune to tarnish, is required, as in electrical contacts... where conditions involve high temperature and product purity, as in the production of lens glasses... where peak catalytic efficiency is needed, as in the refining of high octane gasoline... or where a combination of severe corrosion or erosion must be met, as in the case of spinnerettes for rayon production . . . the platinum metals often prove to be the most economical materials for critical equipment.

Industry is going to higher temperatures and higher pressures. Perhaps your own progress has been blocked by the limitations of materials to withstand such severe conditions. The platinum metals have removed many barriers. Have you considered them for your problems?

Platinum, palladium, rhodium, ruthenium and iridium have unique potentials, well worth your attention. Specialists are prepared to work closely with you in evaluating these metals for new commercial and scientific uses.

As a first step, write us for additional data on the outstanding characteristics and successful applications of the six platinum metals and their alloys – indicating your field of interest or how we might be of assistance.

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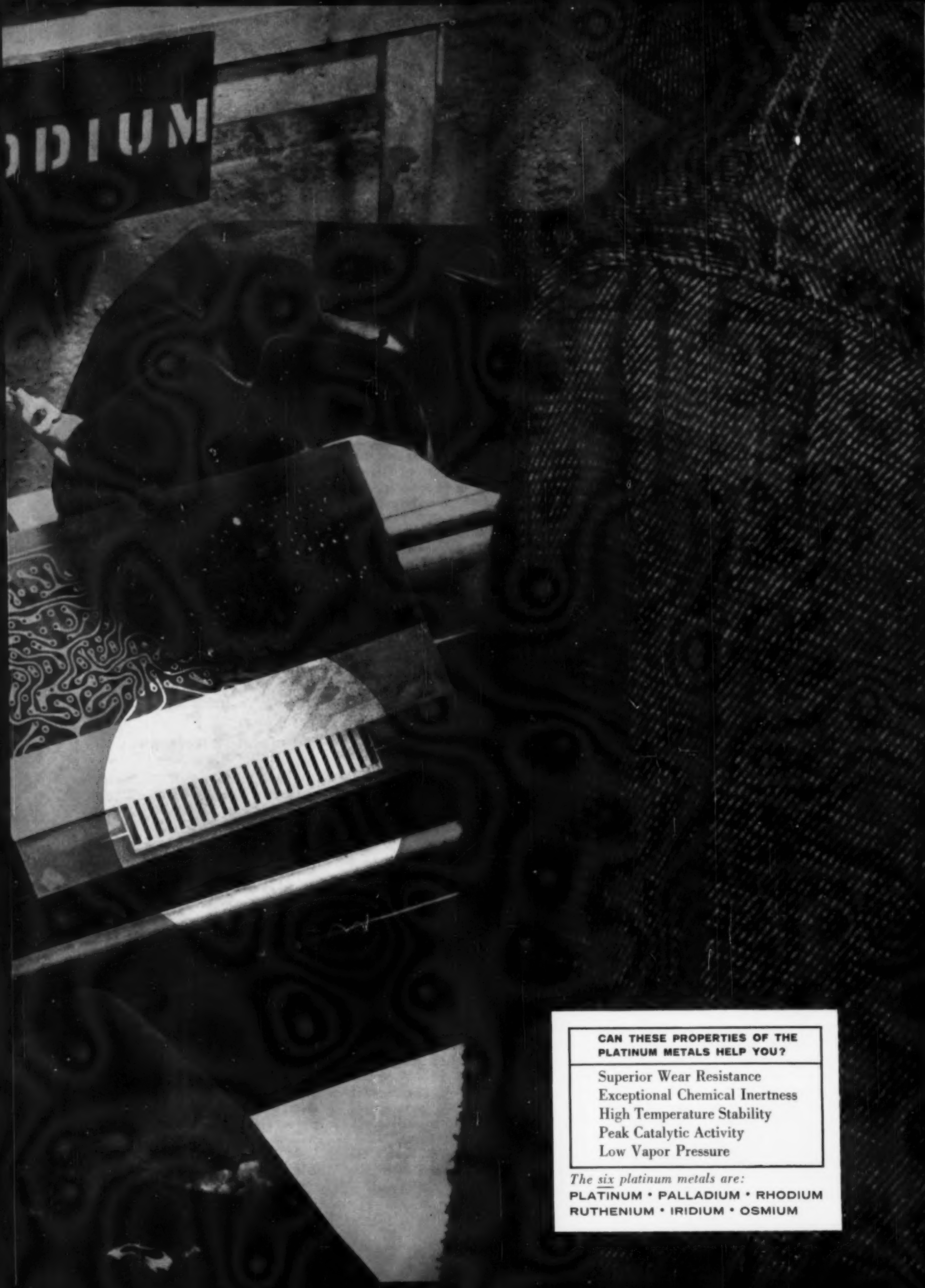
The International Nickel Company, Inc., 67 Wall Street, New York 5, N.Y.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The six platinum metals are:
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RUTHENIUM • IRIDIUM • OSMIUM

IR FEEDBACK *from technical management*

Management machines—pro

Sir:

I found Dr. Rowe's article "Management Machines — A Systems Approach" (Vol. 3, No. 2) timely, accurate, and helpful.

We are interested in the work of persons like Dr. Rowe and in learning of his efforts to discover the basic logic and variables of the management process by which valid and useful statistical-mathematical models can be built.

Equally important, we agree, is the discovery of sets of decision criteria to be used in conjunction with the basic model. We envision models both as streamlining the management process and as a training device.

I would like to concur with the many compliments on your journal. It is fulfilling a major communication need in our advancing research technology.

Dr. Robert B. Sleight
President
Applied Psychology Corp.

Sir:

Dr. Rowe offers some provocative comments on the use of computers in management decision making.

The growth of this area of research has progressed beyond the point where construction of appropriate mathematical models is a novelty, although we most certainly are a far way from the universal adoption of such techniques.

Our most pressing need, at this point, is to demonstrate benefits that can accrue from applying computers to the decision making problems of management. Practical application requires accumulation of a fundamental body of data, specific to the organization concerned, and the use of appropriate sensitivity tests to determine the adequacy and importance of such data.

A realization that critical acquisition of the proper data base is a *sine qua non* for the greater utilization of the computer as a tool in management decision making. Afterwards, I believe we can look forward to new, and perhaps revolutionary, concepts in the functions of the executive.

Herbert W. Robinson
President, C-E-I-R Inc.

Management machines—con

Sir:

Dr. Rowe perhaps typifies the horde of intellectual skipjacks and longheads which has descended upon industry since the advent of the first Sputnik. Armed with a quiver of phrases—"formalized objectives," "conceptual loop control," etc.—these Magi, the new practitioners of sciencemanship, have fled the sanctity of the Ivory Tower in droves and have found seemingly welcome acceptance within the refuge of the Corporation.

Intellectual breast-beating in the market place perhaps salves the psyche of the American business community, which long has been a trifle ashamed of its lack of cultural attainment—according to some correspondents. However, to borrow a page from our learned seer's text, it is my personal belief that we have tended, in business, to over-optimize the parameters within which formalistic socio-scientific reasoning can contribute to the organizational matrix. Further, we have allowed ourselves to become mesmerized by both linguistic goobledygook and theoretical, academic hocus-pocus.

I ask this question of Dr. Rowe: If "the old cliché of profit being the primary objective of business enterprise gradually is disappearing," then what the hell is taking its place?

If Dr. Rowe can explain to me that I'm in the business for some other purpose, I'd be most gratified to give audience to the explanation. Granted, the quote may have been more of a philosophic aside to the purpose of the article, but this doesn't get the good doctor off the hook.

In my part of the country, at any rate, children still are allowed to say "profit" in front of grandparents, ministers, and baby sitters. I hope to God the day will never come when the word need be spoken "out behind the barn."

J. R. Strobel
Dallas, Tex.

Bionic machines

Sir:

The article by Peter M. Kelly, "Bionic Machines—A Step Toward Robots" (Vol. 3, No. 1), did a fine job of highlighting some of the recent work in the tyro science of bionics.

The advent of bionics—and, indeed, the whole cybernetic movement—has ushered in a host of interesting questions and problems of a highly theoretical nature.

Dr. David Ellis
Manager
Bionics & Medical Electronics Group
Litton Systems Inc.

Education machines

Sir:

In "A Trend Toward Automated Teaching" (Vol. 3, No. 1), you have compressed a great deal of material into a short and thoroughly interesting article.

Simon Ramo
Executive Vice-President
Thompson Ramo Wooldridge Inc.

Office copying machines

Sir:

Thank you very much for publishing the article "Speedup In Office Copying" (Vol. 3, No. 1). The tabulation of manufacturers and specifications is especially helpful.

It would be equally appreciated if you could follow with a similar article on photostat-photocopy-camera type equipment more suitable for engineering offices. By "more suitable" is meant equipment which can reproduce with preciseness contour map exhibits, drawings, photographs, etc., with excellent detail exactly to scale or either enlarged or reduced.

C. E. Strain
Consulting Engineer
Atlanta, Ga.

Sir:

We noted with interest your article about office copying. The overall article is accurate, authentic, and well done.

John W. Marsman
Copease Corp.

Research planning

Sir:

Reading the "Feedback," I was startled by the defeatist attitude of your anonymous reader commenting on "Planning Research" (Vol. 2, No. 4). Dr. Gershinowitz's article was superbly conceived and it is to be deplored to have evoked in your reader the feeling of "semiannual ritual . . . of getting management off your back."

While realizing the fact that there are pet projects of the company management which possibly are of minor importance, a budgeting employe should consider them just as thoroughly as his own pet projects. Budgeting, just like research and development, should be scientific, economic, and psychological, which Dr. Gershinowitz implied in his article.

For us who work in research, Dr. Gershinowitz brought home another important fact which so frequently is neglected by some of the managements bent on the philosophy of "fast results." Basic research, applied-industrial research, and product development should go hand in hand, one after the other, in order to make use of all the chances so necessary for success. Shell scientists and budgeteers (management) gave a good example for all to follow.

Francis Schiller
Research Engineer
Pratt & Whitney Co. Inc.

Technical entrepreneur

Sir:

Congratulations on your article "The Technical Enterpreneur" (Vol. 2, No. 2)—more horse sense per line than I have run across in a long time. You correctly have pointed out the reason behind the low "inventive contributions per employe" in large engineering offices.

It would be interesting to see a future article dealing with the problem of just how a system of incentive awards could be established in a large corporation.

Mark Hoffman
Aerospace Propulsion
The Marquardt Corp.

Optical measurement

Sir:

While attending the Technical Association of the Pulp & Paper Industry conference, I picked up a copy of Industrial Research and enjoyed the contents to the extent that the article "An Optical Method for Dimensional Measurement" (Vol. 2, No. 5) has given me a basic idea for a development I have had in mind for some time.

Other articles I reviewed appealed to me because they were practical and form basic fundamentals from which to develop practical ideas.

E. E. Thomas
Executive Engineer
Appleton Machine Co.

Product development

Sir:

Our firm's efforts are devoted exclusively to research and development, and as such, we have found the article "Pitfalls of New-Product Development," by Dr. Harold L. Garbarino (Vol. 2, No. 4), of singular interest. In connection with a company prospectus which we are preparing, we will appreciate your permission to reproduce this article.

Wilson S. Geisler Jr.
Director
Quantadyne

General feedback

Sir:

I am one of the members of the corporate planning staff for my company. One of our major assignments is to find new areas for diversification—areas which have good growth potential for the next decade.

I have been reading Industrial Research for the past year and have found every issue to be so informative and timely that it eventually ends up being routed throughout our whole organization. While there are many good publications covering specific industries, I feel that yours does an outstanding job in furnishing business management with concise analyses for a wide variety of industries. For our purposes, this is pretty close to ideal.

I should like to compliment your editorial group and hope that you can continue to maintain the high standards that each issue typifies.

M. J. Goodfriend
Marketing, Corporate Planning Staff
Continental Copper & Steel Industries Inc.

Sir:

I've enjoyed your journal and have done my bit to spread the news about you. A request for a bibliography from a member of top management on "Corporate Office Research-Control, Organization, Budget, etc." led me to think it would be a good title for a paper in your journal. I am sure a summary of the present state and possible future would be widely read.

Frank G. Bennett IV
North American Aviation Inc.

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Access Time— Main Memory—average	9.0 milsec	______
High Speed Loops—average	1.7 milsec	______
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	RECOMP III	COMPETITIVE COMPUTER
Memory	Disk—Non-volatile	______
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DR. RICHARD E. BELLMAN, *author of dynamic programing theory*

DR. CLEDO BRUNETTI, *radio proximity tube pioneer*

MARVIN CAMRAS, *father of modern magnetic recording*

Introducing

The I·R Editorial Advisory Board

SIXTEEN OF THE WORLD'S foremost living scientists and industrial and government technical leaders have been named to the newly-created Industrial Research Editorial Advisory Board for 1961.

At least 1,000 patents, 112 honorary degrees, and 150 scientific awards are held by the 16 board members. Among them are three past presidents of the Institute of Radio Engineers, and past presidents of the American Academy of Arts and Sciences, the American Astronomical Society, American Association for the Advancement of Science, and American Society of Engineering Education.

Editor & publisher Neil P. Ruzic announced formation of the board in preparation for monthly publication and "to provide the ultimate in scientific communication between members of technical management." Industrial Research will be monthly next October.

The board will function in an advisory capacity to guide the I·R staff of technical consultants and science journalists in the selection of editorial content. In effect, readers will be able to draw upon the diversified talents of the board through the editorial pages of the magazine.

Industrial Research now has the most complete editorial staff of any major scientific or management publication. "This is the first step," Ruzic said, "toward making Industrial Research the world's most significant magazine."

Members of the Industrial Research Editorial Advisory Board, elected for the 1961 term, are:

- Dr. Howard H. Aiken, professor of applied mathematics and director, The Computation Laboratory, Harvard University.

Dr. Aiken is the originator of the MARK I, first automatic large-scale general purpose computer, and co-designer of the MARK II, MARK III, and MARK IV computers. Before joining the Harvard faculty, Dr. Aiken held engineering positions with the Madison Gas & Electric Co., where he was responsible for design and reconstruction of the company's electric generating station, and Westinghouse Electric & Manufacturing Co., where he applied the company's products to the design of electric generating stations.

Dr. Aiken was president of the International Conference on Information Processing held in Paris in 1959. Decorated by five countries and the holder of two honorary degrees, Aiken is the author of numerous papers on computing machinery, data processing, switching theory, and allied subjects.

- Isaac L. Auerbach, president and technical director, Auerbach Electronics Corp.

A pioneer and leading international figure in information technology, Auerbach was one of the forerunners in applying magnetic cores and transistors to digital processing. His achievements in the field of magnetics

DR. LEE deFOREST, *inventor of the triode*

DR. WILLIAM L. EVERITT, *communications engineering authority*

DR. THOMAS J. HIGGINS, *automatic control authority*

DR. L. KERMIT HERNDON, *chemical industry leader*

DeWITT O. MYATT, *technical*

resulted in a major breakthrough that led to the development of military digital communication systems. He designed and developed the static magnetic memory system for the ENIAC computer, the first application of magnetic cores to high-speed coincident-selection memory.

Auerbach also was associated with the development of BINAC, UNIVAC, and military systems such as the SAGE system radar target detection equipment for real-time data processing, and the guidance computer for the ATLAS ICBM. For his services in helping organize the UNESCO-sponsored First International Conference on Information Processing in 1959, he was awarded the Grand Medal of the City of Paris.

▪ Dr. Richard E. Bellman, mathematician, the RAND Corporation; consultant, Hughes Aircraft.

Dr. Bellman is the author of the dynamic programing theory, a mathematical theory with applications in automation and adaptive control. Among his major scientific accomplishments are the theory of stability of various types of equations and processes, and mathematical physics where a new approach, invariant imbedding, is providing solutions to classical problems.

During World War II, Dr. Bellman taught radar for the Air Force, worked on sonar for the Navy, and spent his Army career at Los Alamos as a member of the special engineering division working on the A-bomb. He also worked on the H-bomb as a member of Project Matterhorn at Princeton University. Dr. Bellman has held academic positions at Princeton, Stanford, and UCLA. He is the author of 275 published research papers, 11 books, and five monographs.

▪ Rear Adm. Rawson Bennett, USN (Ret.), recent chief of Naval Research.

Holder of the Legion of Merit with Gold Star, Adm. Bennett has been cited for his design of sonic and supersonic underwater apparatus while attached to the Bureau of Ships, Navy Dept. While assigned to the Bureau of Ships, he served first as head of the Underwater Sound Design section, Radio Div., and later as head of Electronics Design Div.

His second citation was for "exceptional and outstanding performance of duty" in furthering naval research as chief of Naval Research. He retired from the Navy in February, 1961.

During his long naval career, Adm. Bennett set up and ran the technical program of the first Fleet Sound School, directed the Navy Electronics Laboratory; set up and became first director of the Electronics Production Resources Agency, Department of Defense; headed the Mine Warfare Branch, Bureau of Ships; and served as assistant chief of the Bureau for Electronics.

▪ Dr. Cledo Brunetti, president, Grand Central Rocket Co., and former associate director, Stanford Research Institute.

Dr. Brunetti played an important part in the development and production engineering of the radio proximity fuse, a major secret weapon of World War II. He also worked on radio-guided bombs and the radiosonde. He was responsible for liaison of development activities between the National Bureau of Standards and MIT in the Pelican (Bat) Missile project, and served as consultant to the Office of Scientific Research & Development.

A pioneer in the field of printed electronic circuits, Dr. Brunetti also has pioneered development of mechanized electronic production, resistance tuned oscillators, miniature electronics, high reliability electronics, and simplified maintenance design. In addition to academic positions with the University of Minnesota, Lehigh University, and George Washington University, Dr. Brunetti has served as director of engineering research and managing director for General Mills Inc.

▪ Marvin Camras, senior engineer, Electronics Research Div., Armour Research Foundation, the father of modern magnetic recording.

Much of the phenomenal growth in magnetic recording is attributed to Camras' pioneer work in magnetic tape and wire recorders, including high frequency bias, improved recording heads, wire and tape materials, magnetic sound for motion pictures, multi-track tape machines, and binaural sound reproduction.

His magnetic recording inventions have influenced growth and development in motion pictures, radio and television, office machinery, high-speed computers, and other instrumentation.

Along with Thomas Edison, Lee deForest, and Marie Curie, Camras is a recipient of the coveted John Scott medal for his work in magnetic recording. He is the author of numerous articles and holds more than 200 patents for his basic inventions in magnetic recording.

▪ Dr. Lee deForest, inventor of the world's first electronic tube and radio telephone.

Among Dr. deForest's many contributions to the progress of radio and electronics are the first wireless transmission overland, first wireless telegraph between

DR. MERLE A. TUVE, *pulse radio and ionosphere pioneer*

SIR ROBERT WATSON-WATT, *inventor of radar*

DR. CLYDE E. WILLIAMS, *former president of Battelle*

R. HARLOW SHAPLEY, *world-renowned astronomer*

DR. VLADIMIR K. ZWORYKIN, *father of practical television*

ıformation specialist

moving trains and fixed stations, the first radio broadcast, first transmission of voices without wires, first use of radio knife in surgery, first broadcast of opera, first oscillating tube circuits, first use of electronic tube in broadcasting, first electronic musical instrument, electromagnetic phonograph pickup, first transmission of voice by radio telephone from airplane in flight, and the first theatrical presentation of sound-on-film talking motion pictures.

The recipient of numerous honorary degrees, he is a former president of the Institute of Radio Engineers and holds the IRE Medal of Honor, the Legion of Honor, John Scott medal, and Edison medal.

■ Dr. William L. Everitt, dean, College of Engineering, University of Illinois.

A communications engineering authority and technical advisor to the government and military, Dr. Everitt currently is serving on the U.S. Army Scientific Advisory Panel; Technical Advisory Panel on General Sciences, Department of Defense; and as chairman of the Board of Visitors, Signal School, Ft. Monmouth.

He has held academic positions at Cornell, University of Michigan, and Ohio State University prior to joining the University of Illinois. A former president of the ASEE and the IRE, he has received a number of awards, and has authored several books and articles.

■ Dr. L. Kermit Herndon, vice-president, Energy Div., Olin Mathieson Chemical Corp., and senior vice-president and director, Clyde Williams & Co.

Dr. Herndon has had a distinguished career in chemical and chemical engineering research and development. He holds four university degrees in science and engineering and also has had academic training in law. He formerly was professor of chemical engineering at Ohio State University.

As a technical manager, he serves as vice-president and treasurer, Weinman Pump Manufacturing Co.; vice-president, director, Ohio Semiconductors Inc.; vice-president, director, and treasurer, F. W. Bell Inc., and member of the advisory board, Manufacturers & Traders Trust Co.

■ Dr. Thomas J. Higgins, professor of electrical engineering, University of Wisconsin.

Dr. Higgins' major scientific contributions have been in the field of automatic control and electromagnetic theory. His published work to date numbers approximately 140 papers which cover a broad range of interests, including a particular emphasis on the analytic solution of problems in electrical engineering. He has edited some 55 engineering textbooks.

Winner of the George Westinghouse Award in 1954 for his contributions to engineering education, Dr. Higgins has held academic positions at Auburn Intercollegiate Center, Wyomissing Polytechnic Institute, Purdue University, Tulane University, and Illinois Institute of Technology. He is a consultant to industry in the fields of heavy-current bus bar distribution system design and automatic control theory analysis.

■ DeWitt O. Myatt, president, Science Communication Inc., and specialist in technical information and research administration.

As former manager of development for Atlantic Research Corp., Myatt was responsible for central sales, technical personnel, technical library, public and community relations staffs. He has served as editorial consultant to the Atomic Energy Commission and as managing editor of Industrial and Engineering Chemistry.

His experience includes work as a chemical engineer for the Tennessee Valley Authority in process development of pilot plants for production of alumina from clay, copper arsenite, electric furnace phosphates, and phosphatic fertilizers.

■ Dr. Harlow Shapley, renown lecturer on cosmography and former director of the Harvard College Observatory, Harvard University.

Recognized as the world's greatest living astronomer, Dr. Shapley has been awarded honorary degrees by 16 universities and is the recipient of numerous awards from 10 foreign countries. He is the author of six books and more than 200 scientific articles, chiefly in the field of astronomy.

Among his major contributions in astronomy are the development of a period-luminosity relation for cepheid variable stars as a measuring device for the universe; discovery that the center of the galaxy is some 25,000 light years distant from the earth in the direction of Sagittarius (thus showing the eccentric position of the earth and sun in the stellar universe); development of the pulsation theory of cepheid variables; and demonstration of the associated variability of stellar spectra.

■ Dr. Merle A. Tuve, director, Carnegie Institution, and pioneer in first pulse radio and ionosphere experiments (which later became radar).

Dr. Tuve's scientific accomplishments also include research on the cosmic ray telescope, demonstration and measurement of proton-proton and proton-neutron

(continued on page 74)

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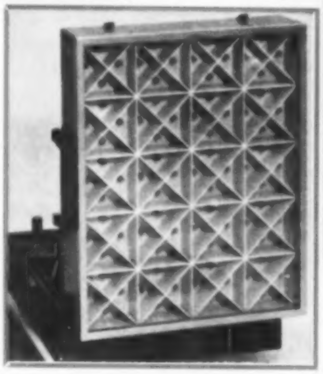

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THE BASIC APPROACH *to product development is illustrated in these novel developments which highlight the work of product design students at Illinois Institute of Technology's Institute of Design. Director Jay Doblin's design philosophy of product development results in such basic assignments as: "design an economical device for sitting," yielding (1) The tongue-in-cheek "ultimate" in contour chairs. But also serious products such as: (2) A one-handed typewriter, freeing the other hand for telephone, books, etc. Various combinations of nine keys produce the desired letter. (3 and 4) A long-distance typewriter that flashes a light message, letter by letter, as fast as the operator can type. (5 and 6) A battery-operated stop-and-go light with piercing horn designed to replace the often-misunderstood police whistle. (7) An array of ball-point "writing tools" designed to fit instead of fight the hand. (8) A swimming machine that can extend a swimmer's distance ability by many miles. (9) A device to mortise doors automatically for locks and hinges. The latter tool would simplify large-building construction where hundreds of doors have to be hung.*

(More idea photographs follow.)

THE BASIC APPROACH TO PRODUCT DEVELOPMENT

by **Dr. Charles H. Moore,** *technical director, Copper Products Development Assn.*

IN RESEARCH-MANAGEMENT CIRCLES research seems to be either basic or applied. As a result, depending on whom you work for and your objectives of the moment, many of you align yourself with one group and adversely criticize the other.

If your job is concerned with industrial-product development, you hasten to declare yourself an "applied research man" to impress management with your practicality. Companies paying for product research naturally want results they can see, touch, and merchandise, and you feel you immediately must establish your down-to-earth, realistic attitude.

In making this quick alignment with applied research, however, you may be eliminating the chance to give your company the maximum in product-development service. The choosing of sides condones and perpetuates a needless word-distinction (basic versus applied), complicates the work ahead, and possibly even makes its most productive phases impossible.

For when it comes down to cases, no matter how practical a product-development program, it can't be organized, systematized, and planned logically unless you get down to basic principles. And when you do, you're flirting with a basic-research approach, and unearthing some fact vital to the program. Why, then, hamstring yourself at the start by implying disaffection with a tool that might be most useful?

Fear of the basic

Current development efforts of many companies are thwarted because their managements do not understand the basic-research approach and therefore are afraid of it. Such fear is groundless; it comes

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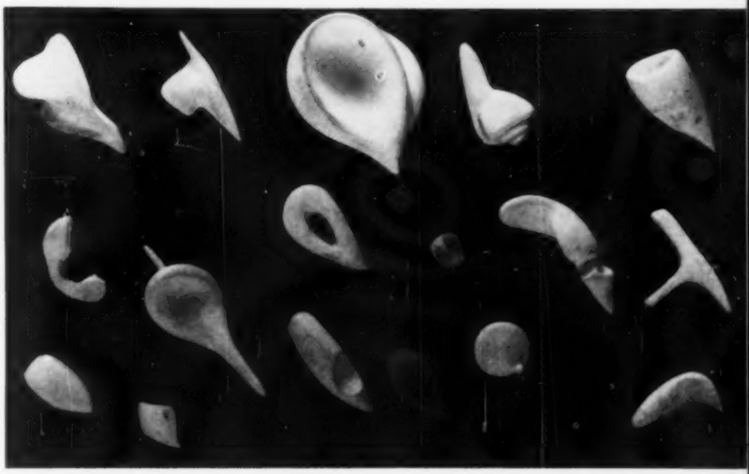

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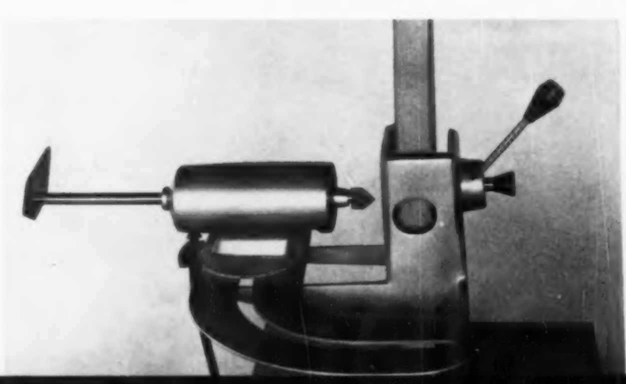


from confusing the basic-research *approach* with basic-research *investigations.*

The latter can be impractical if not directed toward some product goal; the former always is practical. The basic-research approach merely is the application of modern scientific knowledge to systematize outlook and efforts.

Before exploring this basic-approach concept in detail, it is desirable to consider the nature of product development itself. First of all, innovation—mere design change—is not product development, and any company operating under the illusion that it is eventually will begin to decline.

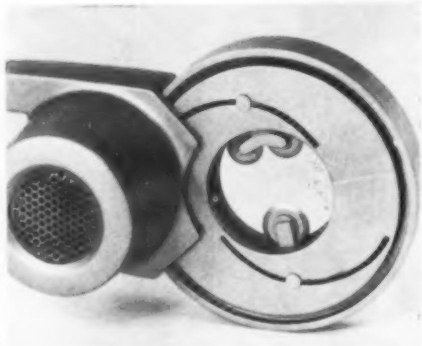
Innovation has a place as a tool for merchandising. But no matter how you square or round the corners of a refrigerator, or how many times you change it from white to pink to lemon yellow, you still will be out of the race when electronic refrigeration comes along — unless your pink or yellow refrigerator also has a thermoelectric cooling mechanism.

Distinct from innovation are two areas of development—product improvement and invention of new products. Product improvement, which incorporates some new scientific or technological principle, makes the product more serviceable. Unless it allows a price reduction, the improvement may not be apparent to the customer at the time of purchase, but it will show up later in the product's efficiency or longevity.

Daring in two sizes

More dramatic is the development of totally new products. Every firm involved in R&D hopes to bring out radically new products, but relatively few companies have the daring and confidence in their technical abilities to succeed. It seems that the really big companies, which can afford to lose, and the small companies, which have little to lose, are the ones most likely to come through with startling new developments.

For example, giant DuPont came up with nylon, then mylar, then delrin; General Electric synthesized diamonds. At the other extreme of company size, the then-small Haloid



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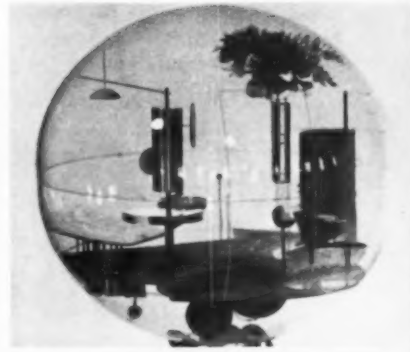

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COUNTLESS PRODUCT IDEAS
result when the basic approach is applied. More Institute of Design-developed products are: (1) An electric conduit cutter. (2) A battery-powered micrometer with inside and outside calipers. (3) An electric device to bring heavy objects such as refrigerators up stairs (cleats engage the edge of each stair). (4) A spherical bathroom that can be produced as one unit. (5) An Arctic face protector with air-insulated glass and a crushable rubber mouthpiece to eliminate frost. (6) A power rasp with reciprocating drive. (7) A ground-effects vehicle that tips like a helicopter for forward movement, flies three inches above the ground at 25 mph.

Xerox brought out xerographic copying, and tiny (at the time) Polaroid produced a revolutionary camera.

In between these extremes rests the great mass of corporate conservatism, playing it safe by selling essentially the same products year after year.

But regardless of their size, companies seeking progress will find that in either area of development—product improvement or new product invention—advancement almost invariably depends on some new association of ideas or breakthrough in technology that can be brought about most readily through a basic-research approach.

With modern research procedures so well developed, it is archaic and costly to use the Edisonian try-everything-on-the-shelf approach to product development. It is going back to 1910 and ignoring a half-century of progress. Even though much of our industrial progress has been made by empirical means, technology now is too involved to expect fruitful results from such methods. Too many permutations of fact and data are possible to make hit-and-miss techniques feasible.

New approach for an old industry

The copper industry, for instance, is very old—copper mining having been carried on for at least 6,000 years. In this time, traditions have developed and ideas for cultivating markets have become almost institutionalized. Thus it is remarkable to see the industry settle on an approach that surmounts the limitations of these traditions and goes directly to the inherent characteristics of the copper atom and the copper ion for guidance.

The copper industry now is using the same approach to its product research as the dynamic young electronics, semiconductor, and missile industries.

Once the copper industry's approach was spelled out, it became apparent that such an approach was not something to be afraid of; it merely had expressed a systematized philosophy for action that would prevent spending too much time and money in blind alleys.

This philosophy included all the ideas that one might pursue by sheer empiricism, provided room for developments not likely to come otherwise, and indicated cutoff points in planning and laboratory investigation. Most important, the approach put the research people in an expansive frame of mind, rather than in a restricted one.

Starting with the copper atom to determine the courses to follow, the Copper Products Development Assn. began by asking "What are the characteristics of the copper atom that can be exploited to create new markets for copper?"

This approach is different from asking what properties of the metal might be exploited, since the properties of the gross metal are in themselves gross phenomena and, therefore, are less definitive than the characteristics of the atom. Thus, to say that copper has high electrical conductivity would provide a more restricted base to work from than to say that its single fourth-shell electron is easily detached under low-activation energy.

With the characteristics of the copper atom in mind, it immediately becomes clear that many of the metal's virtues, opportunities, and problems are related to the activity and mobility of that atom when it has lost one or more orbital electrons. In other words, many of the properties observed in the gross metal are related to ionization and the specific behavior of the several copper ions.

Ionization: asset and liability

Copper is a good conductor because it ionizes so easily, but the tarnishing problem with copper and brass products is related to the same ease of formation of ions and their mobility. The activity of the ion and its ability to vacillate from one valence state to the other is a tremendous asset when copper is used as a catalytic agent in organic synthesis. Yet this activity and vacillation cause difficulties in certain architectural and mechanical products.

At this stage, the Copper Products Development Assn. had the basic ingredients for a systematic program of research and could build

As technical director of the Copper Products Development Assn., Dr. Charles H. Moore is widely experienced in the management of product R&D. He has specialized in metals, solid state physics, and physical chemistry. Formerly, he was with The Carborundum Co., National Lead Co., and P. R. Mallory & Co. At National Lead he developed the single-crystal titania gem, contributed to other developments in lightweight concrete, semiconductors, electronic components, bright paint pigments, and special metals and alloys. He was educated at the University of Virginia and Cornell University, receiving his doctorate at Cornell in petrology.

around the concepts of products that:

- Take advantage of the activity and mobility of the copper ion.
- Are unaffected by these phenomena.
- Suppress or render ineffectual the activity and mobility of the copper ion.

Thus, three possible lines of attack were outlined, based on the most pronounced (and therefore, possibly, the overriding) characteristics of the copper atom. But a fourth concept immediately was obvious—the possibility of products that might result from modifying the very nature of the copper atom.

A few years ago, such a concept would have seemed absurd. In light of what has been accomplished in the semiconductor field with electron donors and electron acceptors, however, it would be folly to rule out this possibility.

Concepts into projects

Translating these basic concepts into project language, four types of projects have been included in the 1961 program: *copper as a chemical raw material*, *copper as a mechanical material*, *surface chemistry*, and *atomic chemistry*.

With the philosophy delineated and interpreted in terms of categories of project, things began to fall in place, *and the very act of going through the systematization procedure suggested specific studies and the weight that should be given to each*. It is outside the purpose of this article to discuss all the project ideas the association will follow, but some examples will show the practicality of the approach.

Taking advantage of the copper ion's activity and mobility leads into studies on the use of copper compounds for catalytic purposes—such as to promote organic reactions or to oxidize unburned hydrocarbons and break up nitrous oxides in automotive-exhaust systems. Or one may envision a unique series of chemically bonded refractory-oxide coatings for copper wire produced through vapor deposition and stoicheometric-replacement processes.

Research built around products that do not depend upon the copper ion's activity will include much of the work on applications for copper in the building, electrical, electronic, and transportation industries. Strictly speaking, ion activity is not always avoided here when it is beneficial, but it at least is taken into account as a source of trouble when it is harmful (for example, the dezincification of brass).

Under the program's third phase—suppressing activity and mobility of the copper ion—will come work on prevention of tarnishing, including studies on surface passivation, organic and inorganic coatings for protective purposes, vapor applied films, etc., to solve many of the difficulties experienced in the present use and acceptance of copper products.

Changing the copper atom

The final category — structural modification of the copper atom — will have as its ultimate objective the development of unique and unusual materials. Studies will be fundamental in character, long range

"Engineeringwise we're content with our product, but glamorwise, no!"

in outlook, and will involve atomic physics and some of the newer technologies used in semiconductor and electronics industries. It is now known that at extremely low temperatures the conductivity of copper can be increased by several orders of magnitude. Obviously, some change takes place in the copper atom. Perhaps such changes can be made to occur at room temperature.

This approach to program planning is not sensational or revolutionary, nor is it scientific legerdemain. It merely is an outlook — a way of thinking — starting from principles and expanding outward. By such an approach the copper and other industries can attack the problem of new products and markets more systematically. Each research proposal must be viewed from the theoretical standpoint and planning must be scientific rather than empirical.

It is very easy in all industrial research to seek shortcuts, to plunge ahead hopefully rather than systematically. Such plunging frequently works — but in the complex technology of today, it is too costly and usually takes too long.

Most industries need many new products to create markets for the production of which they are capable. In product development, they do not have time to try everything on the shelf. Rather, they first must determine that their research ideas are based on sound principles, and then move systematically into development of applications.

Success-or-failure factors

While this article is concerned primarily with a basic approach to product development — a philosophy which will provide a solid foundation for any R&D effort — certainly many other factors enter into the conduct of a research program, and some of them can spell its success or failure. The discussion would not be complete without at least a quick look at a few of the leading factors:

- *Laboratory controls.* In some laboratories today, a large part of the research scientist's time is spent in paperwork required by the comptroller's office. Much has been written on this problem, the important part of which can be summarized by saying that a corporation should hire the best technical manager it can find; require from him an annual budget and a program to be approved by top management and marketing; supply him with accounting aids so he can control project expenditures; and require a year-end justification for money spent against technical progress achieved. If the technical manager is wise, he will keep the routine-paperwork load on his creative men to a minimum.

Is control needed in the research operation itself? Yes. A lot of it is necessary to keep projects on the right paths and prevent waste of time. But it is control of technical orientation that is required, not control of every action of the scientist.

- *Development cutoff point.* The penchant of research men for product perfection is one that management must recognize and be on guard against. In some companies financial problems arise because they

will not freeze models and put them into production. A firm can research itself out of business that way. Often, a passable product should be brought to market quickly, and the pursuit of improvement can continue in later models.

■ *Comprehensive attack.* The shotgun attack in product research is a bad habit industrial management has picked up from the military. In weapons research, where national security is at stake, it is pardonable to waste most of a research budget on fruitless efforts in the interest of speed. But in commercial-product research, we should take time to judge which of several alternative approaches is the most plausible.

■ *Market research.* When properly performed, market research can prevent wasted effort. A danger spot, however, lies in the fact that markets in the offing when a research program is initiated may be much more important than those being tabulated and appraised by the market study. When used to determine the worth of technical research, a study should be done in depth, and in consultation with research scientists.

In evaluating product ideas, another danger can be found in too much knowledge of the industry. A man who has been in a business for many years has heard, investigated, and rejected most suggestions a newcomer is likely to advance. As a result he may listen to the freshman with impatience. One day the experienced executive finds the rank novice has assembled in his garage a gadget that represents a significant contribution to the field.

■ *Creativity.* We make much ado in research about eliciting ideas from our technical people—harnessing their creativity. Some psychologists contend that an intelligent person rarely uses more than 10 to 15% of his creative ability. Various polls of research workers have shown that they, themselves, feel that management rarely draws from their best efforts and even, in fact, believe that management sets up barriers to prevent creative functioning.

For example, a study showed that scientists and technologists feel as much as 90% of their potential output is lost to their employers! This startling conclusion came from a questionnaire poll of technical employes in 50 aviation and electronic companies, educational institutions, and research and engineering-consulting firms.

According to the respondents, chief factors detracting from re-

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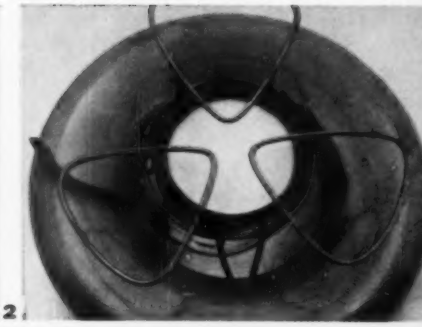

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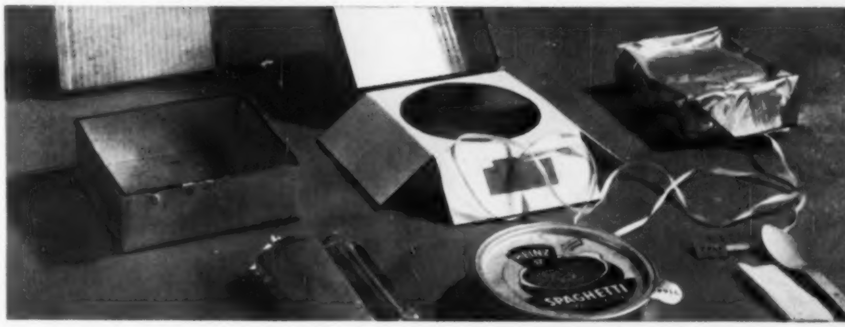

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SELF-LIGHTING BUOY *(1) that turns itself on when the sky darkens, because of storm or nightfall, flashes an intermittent bright light; sun powered, it stores energy during daylight in solar converters around the rim. Other basic ideas turned into products are: (2) A butane-gas camp stove that heats a pot placed on grids. (3) A hot meal package that starts with the pull of a string, which dumps water into carbide, generating heat, and cooking prepared food. Designed for civilian defense, the packages can be air-dropped, are so small that citizens can carry a dozen of them in a briefcase and disperse rapidly. (4) A one-piece metal chair (which won the recent Alcoa Student Awards competition). It can be mounted on subway station walls or on a stand. (5) A utility police car to replace three-wheelers. It will go 85 mph, carries stretchers and other emergency equipment.*

search productivity were: work beneath their abilities, assignments of little or no value, duplicated effort, unnecessary supervisory duties, and fruitless conferences.

Recently a professional opinion-research organization, in interviewing 622 scientists and engineers and 105 executives in six major corporations, found that 72% of the technical people thought that management misused their talents. Cut it as you may—discount the extremes and make allowances for the normal human propensity for a man to underrate his assignments (or overrate himself)—and the evidence remains that present research and product-development processes leave much room for improvement.

Forced empiricism

When a research man is not permitted to do his work scientifically, when he is told to be "practical" and find an easy solution to the problem, when he is forced into a series of haphazard empirical experiments—his contention of management-imposed obstacles would seem justified.

One advantage of a basic approach in product development is the attitude of research scientists working under such a plan. A physical chemist, a PhD, who had been instructed to establish validity of a principle before proceeding with a line of complex investigation, expressed his gratitude by saying that he had never expected to be told to conduct a research study the way it should be conducted! Letting a research man know you want him to use all of his scientific knowledge and training and to program his work rationally stimulates his enthusiasm.

Perhaps a first step in getting the creativity we talk and write so much about is using the basic approach in research and development planning. If we do, we may discover that the "impracticality of basic research" is an irrational bugaboo.

A point many management men forget is that most of today's new products are not mere gimmicks derived from common-sense association of facts (although there still is much opportunity for such inventions). Most new product developments are exceedingly complex technically, saturated with scientific know-how. To make product advances more significant than those of competitors, a company must acquire a deeper knowledge of pertinent technology. No firm can get this knowledge by hit-or-miss methods or by concentrating on superficialities. ■


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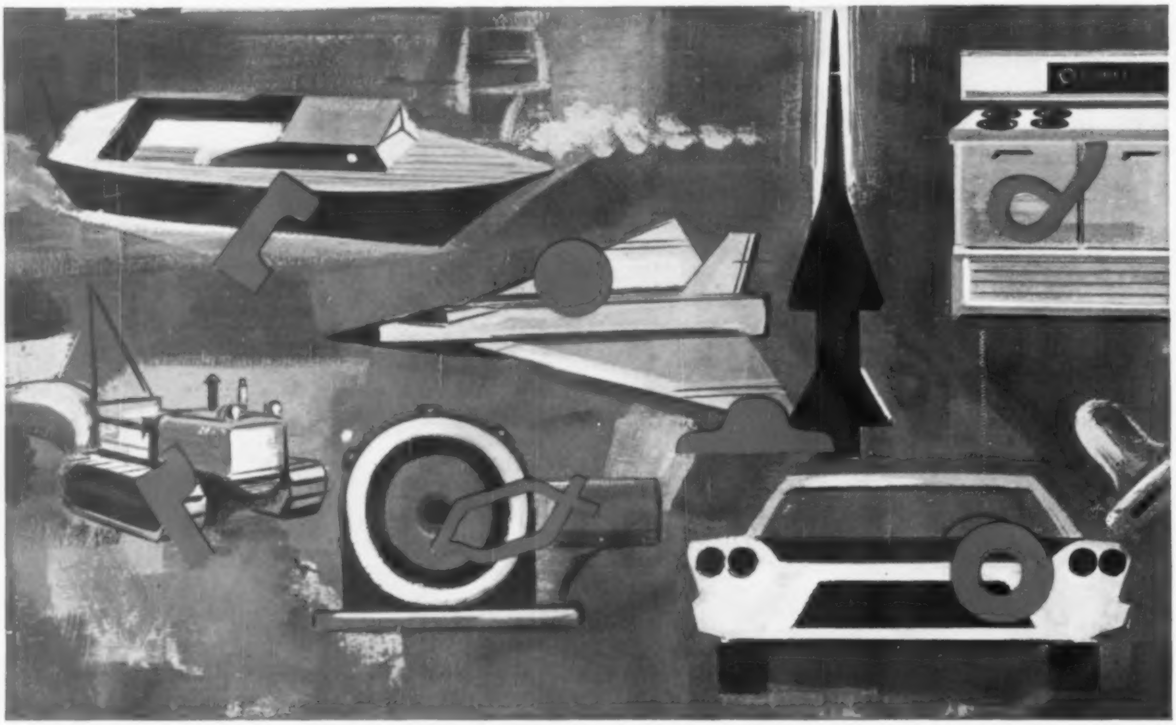

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RESEARCH

TRENDLETTER

Apr-May, 1961

Dear Sir:

The increased importance attached to the role of information retrieval in technical organizations is evidenced by the number and frequency of articles being published on this subject. (See the special section on information retrieval beginning on page 33.) The world's technical journals carried about 60-million pages of scientific reports during 1960. Add to this the volume of reports resulting from government-sponsored research and the problem is apparent.

In pre-Sputnik days little attention was given to information generated overseas. Since then several steps have been taken. For instance, in 1958, Public Law 480 was amended to permit the use of foreign currencies accumulated through the sale of U. S. agricultural equipment abroad, for the translation of large segments of the technical literature published in Russian, Polish, and Serbo-Croatian.

Translation contracts in Israel, Poland, and Yugoslavia, when completed, will make available approximately 66,000 pages of significant scientific literature.

Information volume also has been increased by a list of Russian scientific journals available in English, published by the National Science Foundation; a summary of the status of scientific progress in Communist China, by the Institution for the Popularization of Science; and the dissemination of English abstracts of technical articles of the Soviet Bloc and the Chinese Mainland, by the Technical Services Dept., U. S. Dept. of Commerce.

The National Library of Medicine has requested proposals from electronics firms for the development of a medical literature analysis and retrieval system. Among the new systems under development and test is an "electronic library" capable of up-dating itself by rejecting redundant information. Developed by Lockheed Electronics Co., Plainfield, N. J., the machine permits the user to determine the completeness of the search by specifying the amount of time available for searching.

And, as if the quantity of information is not gigantic enough already, the State Scientific Technical Press for Machine Construction Literature (USSR) has announced that it will publish a 100-volume engineering encyclopedia!

thermoelectricity

Recently announced price reduction on thermoelectric elements by Materials Electronics Products Corp., Trenton, N. J., and price projections based on quantity production are certain to bring more new products based on the principle of thermoelectricity in the near future.

A small thermoelectric refrigerator with a capacity of less than one foot and capable of freezing a tray of ice cubes in about six hours is among the new products recently announced. Norge Div. of Borg-Warner Corp., Merchandise Mart Plaza, Chicago 54, has started production on 500 of these units for installation in rooms of the Sheraton-Chicago Hotel.

A new group of thermoelectric materials based on the use of samarium and cerium sulfides are under development by Westinghouse Electric Corp., Box 2278, Pittsburgh 30. The compounds are said to be stable at temperatures as high as 2000F and to exhibit good thermoelectric efficiencies up to this temperature. The materials are expected to aid in development of better generators for direct conversion of heat to electricity. (Energy conversion will be the subject of a special edition of Industrial Research in October.)

computers

First computer completely designed by a computer has been announced by Bell Telephone Laboratories, 463 West St., New York 14. The entire logic network of the digital computer, consisting of 47 sub-assemblies, has been built from wiring diagrams, assembly information, and parts lists produced by a specially programed, general purpose digital computer. (See photograph No. 1.)

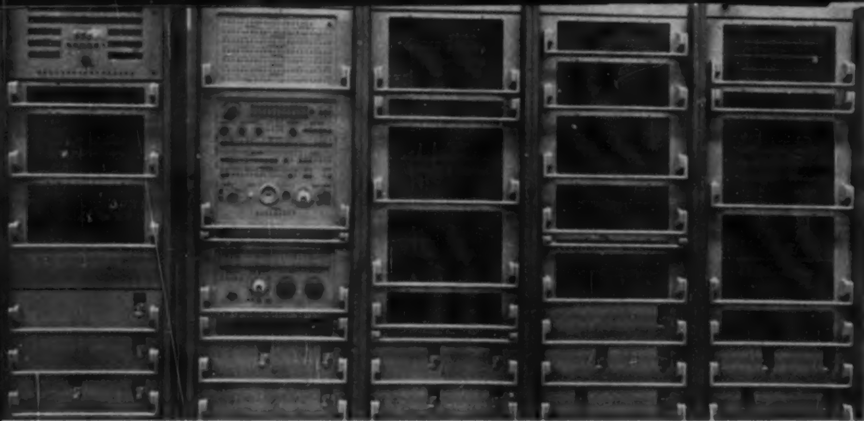
Shell Oil Co. engineers, 50 W. 50th St., New York 20, have devised a special logic system that enables a computer to design the optimum plant for producing a particular chemical from information on processing the chemical which has been fed to the computer. The computer's design reduced the cost of producing the chemical by 5 to 10%.

A multi-purpose industrial control system designed to sample and interpret data in the petroleum refining, chemicals, steel, paper, cement and utilities, and many high-volume manufacturing operations has been introduced by IBM's Data Processing Div., 112 E. Post Rd., White Plains, N. Y. Known as the 1710, the system is IBM's first machine entry in this fertile field.

Electronic action can take place at a pace approximating 186,300 miles per second--the speed of light--with a new computer circuitry developed by RCA's Electronic Data Processing Div., 30 Rockefeller Plaza, New York, in a development program sponsored by the Navy Bureau of Ships. Ultimate goal is an ultra-high-speed computer of truly miniature size and unbelievable speeds.

The RD-900, a new system developed by the Laboratory for Electronics Inc., 1079 Commonwealth Ave., Boston, can store up to 50-million characters, select them at lightning speeds, and immediately display the information on a television-type screen.

Stored information cannot be lost during readout or because of power shutdown or failure with a new high-speed, word-organized, electrically alterable random-access memory system developed by the Air Arm Div., Westinghouse Electric Corp., P. O. Box 746, Baltimore, Md. Design techniques are expected to be significant in military and special industrial control applications. (See photograph No. 2.)



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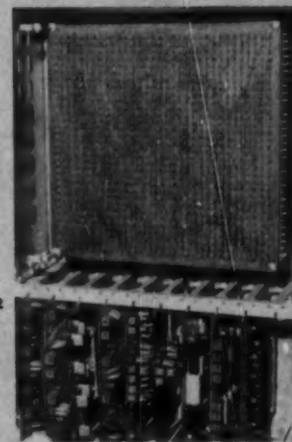

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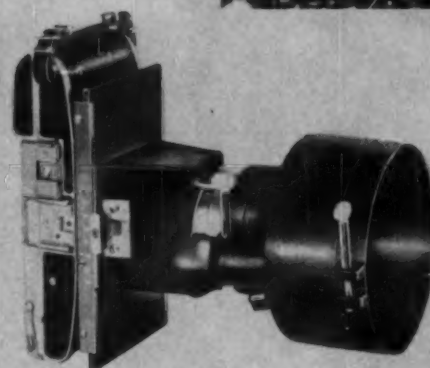


5

Pneumatic devices may be down, but they are not out in the computer field. Kearfoot Div., General Precision Inc., 1150 McBride Ave., Little Falls, N.J., has under development a pneumatic digital computer which will occupy a cube less than three inches on a side. The device will be able to operate from minus 100F to plus 2000F without special provisions for heating or cooling, and in almost any radiation environment since it has no electronic or solid state components.

photography

A cathode ray tube using fiber optic "light pipes" principles has been developed by the Electron Tube Div., Litton Industries, 960 Industrial Rd., San Carlos, Calif., for direct optical printing at high speed on film and other types of light-sensitive materials. A complete digital identifying description can be recorded or interrogated in as little as 50 milliseconds or less. (See photograph No. **3**.)

Space Technology Laboratories Inc., 8929 S. Sepulveda Blvd., Los Angeles, has announced development of a camera capable of shutter speeds up to 2 1/2 billionths of a second--twice as fast as any previous photographic technique. Shown in photo No. **4**, the camera is based on an image-converter technique and new concepts of fast pulse circuitry, permitting electronic shuttering, light amplification, and movement of the image rather than the film. A new RCA developmental tube serves as the electronic shutter.

Up to nine different trace exposures per print are possible with the new oscilloscope trace recording camera shown in photo No. **5**. The device is a development of Electronic Tube Corp., 1200 E. Mermaid Lane, Philadelphia.

instruments

A new electronic barometer that projects its findings on an illuminated electric scale, shown in photograph No. 6, is said to be the most significant design improvement in barometers since their invention 300 years ago. Developed by The Siegler Corp.'s Olympic Radio and Television Div., Long Island City, N. Y., the device produces exact printed paper tape readouts at 12-second intervals.

Build-up of static charges on plastic-faced instruments can be eliminated with a new chemical fluid introduced by Weston Instruments Div., Daystrom Inc., 614 Frelinghuysen Ave., Newark, N. J.

new processes

An economical process for purifying aluminum sulfate has been developed through the pilot plant stage by Olin Mathieson Chemical Corp., 460 Park Ave., New York 22. The development has been termed an important breakthrough in the search for a commercially practical way to make aluminum from common clay. (Photograph No. 7)

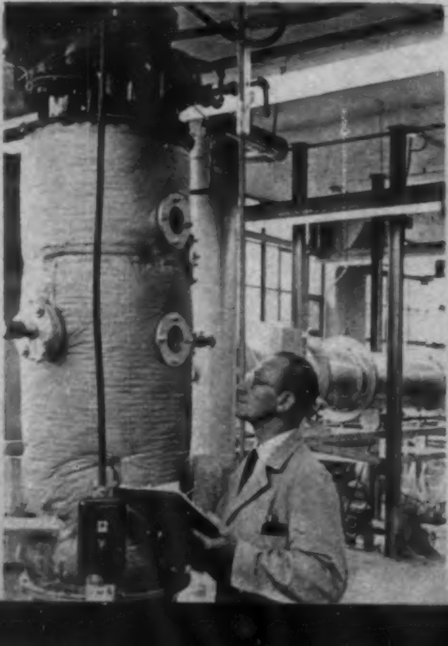
A new chemical process for the production of a new high-strength plastic has been announced by Celanese Corp. of America, 180 Madison Ave., New York 16. The plastic promises to replace millions of pounds of metals and other plastics in volume markets such as automobiles, appliances, and many other applications. The plastic is classified chemically as an acetal co-polymer (giant molecule).

now available

Development of a solid state device capable of producing random noise across a white noise spectrum has been revealed by Solitron Devices Inc., Norwood, N. J. Called a Sounvister, the new device will accelerate both military and commercial research and development in the sound field.

Modification of processing techniques has resulted in tripling the strength and doubling the flexibility of graphite cloth--a high temperature material for missile components--according to National Carbon Co., a division of Union Carbide Corp. 270 Park Ave., New York 16.

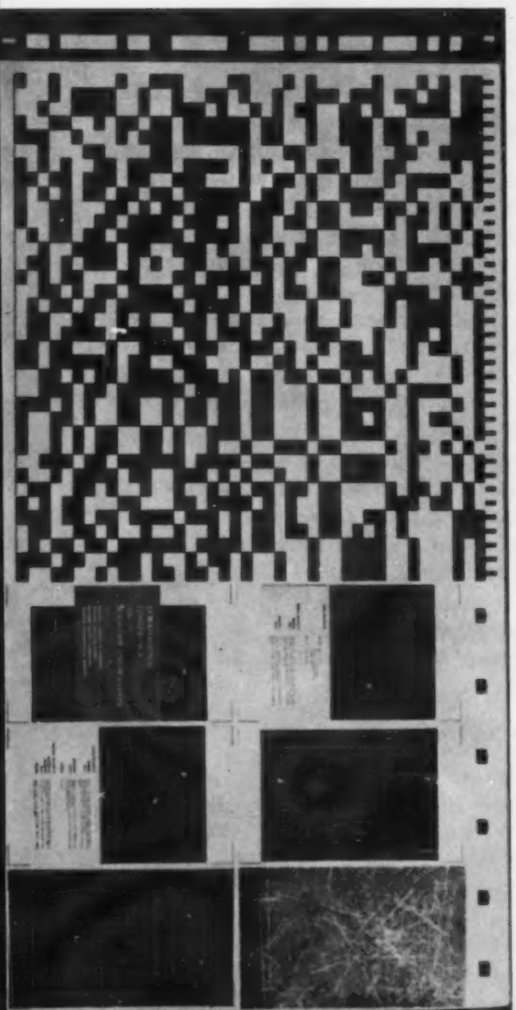
6



7

INFORMATION RETRIEVAL

a special section



Pitfalls of Information Retrieval

by **Harold S. Sharp,** *AC Spark Plug Div., General Motors*

ENOUGH TECHNICAL INFORMATION to fill seven sets of a standard 24-volume encyclopedia is ground out daily around the globe. The information stream is growing exponentially with the rising tide of technical progress. By 1965 you will be expected to absorb roughly double the information currently disseminated.

Each scientific breakthrough breeds new discoveries. Lee de Forest's invention of the basic vacuum tube in 1906 fathered an incalculable number of specific-purpose tubes. These, in turn, led to further developments in electronics, until today that field embraces many specialized areas undreamed of a decade ago. Again, Nikolaus Otto's internal combustion engine, developed late in the 19th century, led to vast improvements, modifications, and applications of the internal combustion principle. Many other examples could be cited.

The explosive increase in the number of discoveries growing out of research and development is accompanied by a corresponding increase in pertinent literature. At least 50,000 technical journals now are being published, most of them on a monthly basis. Books, reports, technical documents, and other written matter come off the press in an ever increasing stream. In some technical areas the literature output rate doubles every 10 to 15 years.

While much of it is trivial, a great deal is highly significant and extremely important to current research problems.

Cheaper by the book

Prior to embarking on a laboratory project, a thorough search of available literature should be made, simply because library research costs less than laboratory research (despite opinions to the

contrary). By devoting a portion of project time to a literature search, it is possible to avoid repeating work already completed by others—for a savings in effort, time, and money.

Esso Research & Engineering Co., for example, saved a month-long exploratory program budgeted at thousands of dollars when an information researcher came across a technical monograph from Sweden. In another case, a literature search eliminated testing of more than 100 chemical compounds when information revealed similar work had been done by others.

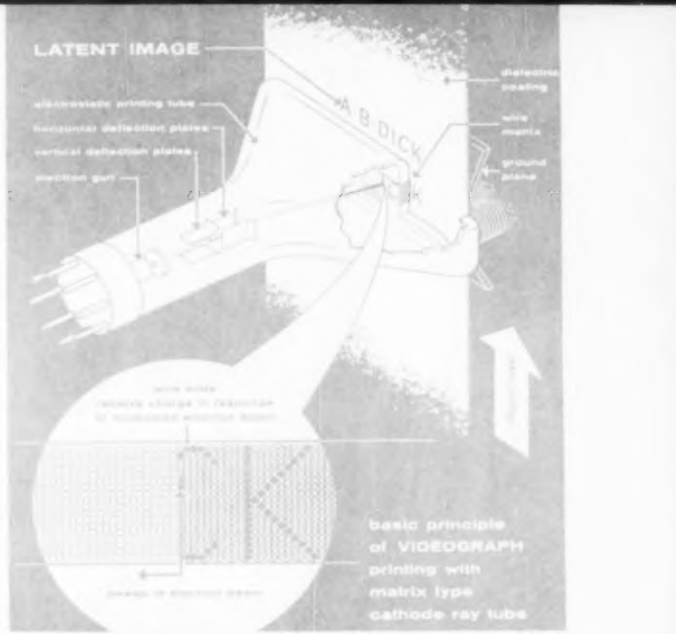
As the volume of technical publishing increases, conventional hand methods of conducting literature searches are becoming outdated. Information on a given subject may be scattered through countless sources. Even large libraries such as the Library of Congress, with more than 30-million publications in its collection, do not profess to have all data on all subjects. And even utilizing the most up-to-date reference tools, it is extremely difficult to locate much of the information available.

A vice-president for research has said "*if a research job costs less than $100,000 it is cheaper to do the research than to find out if it has been done before.*" This may be an exaggeration. Many instances can be cited where a duplication of laboratory experiments was avoided because a comparatively inexpensive literature search disclosed already-determined answers to research questions.

Man versus machine

Numerous solutions to the problem of machine retrieval of information are being developed. The large information center of tomorrow will employ, to a large extent, machine retrieval techniques rather than the hand searches used in most libraries today. Hand methods are time consuming and offer no assurance that all information on a given subject has been located. Machine methods, because of enormous operating speeds, currently can search as many as 100,000 documents an hour, and the rate is expected to increase.

Before joining AC Spark Plug, Harold S. Sharp was chief librarian for Farnsworth Electronics Co. and Rogers Center Graduate Dormitories. He holds a BS in business administration ("with distinction") and an MA in library science, both from Indiana University. A former paratrooper (128 jumps), he served 10 years with the U.S. Army Quartermaster Corps as a captain. He has lectured extensively before business groups on various aspects of special librarianship and has contributed articles on business management and library science to business and scientific publications.



MONOSCOPE CHARACTER GENERATOR *is the heart of A. B. Dick's electronic display systems, and converts digitally coded information into video-type signals for presentation on television monitors. The system permits high-speed readout from remote computers.*

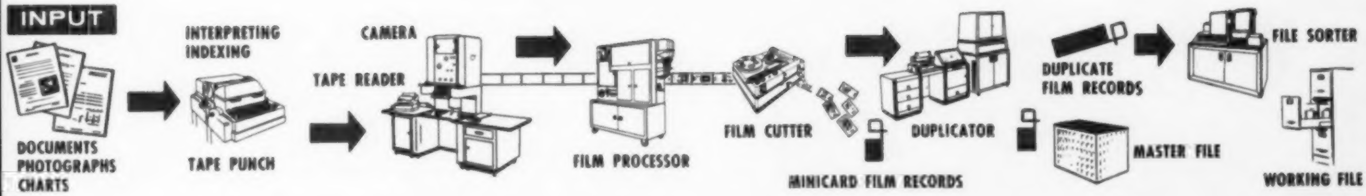
Machine searches never will replace hand methods completely. Use of a machine to retrieve information readily available from immediate sources would be time consuming and inefficient. By way of analogy, simple addition or subtraction can be performed quickly with only pencil and paper; programing such operations for an electronic computer would be ridiculous.

It is equally so with information. Many isolated facts—the telephone number of a subscriber, the logarithm of a number, or the melting point of a particular alloy—can be determined quickly by consulting a telephone book, a table of logarithms, or a metals handbook. When, as in those examples, a single fact is sought, hand searching methods are efficient if the universe to be searched is comparatively limited and has been properly indexed (as with telephone numbers). Machine searching becomes preferable to hand methods when the universe becomes large, and information, while identifiable, is scattered throughout the universe in random fashion.

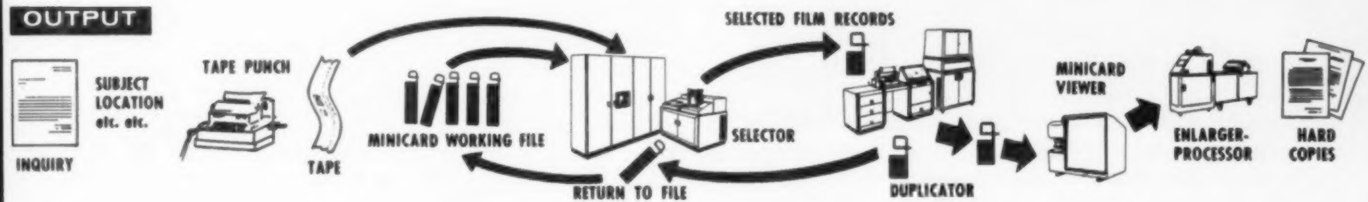
Controlling the 'universe'

Controlling factors are whether the universe has been indexed, and the size of the universe. It is not possible to retrieve a specific bit of information from a universe unless that information has been identified previously to distinguish it from all other bits of information.

Without indexing, information retrieval becomes an unworkable hit-or-miss proposition. *(A cartoon shows a woman consulting a telephone book, saying to her husband, "This may take a while. I don't*



INPUT AND OUTPUT FLOW CHARTS of the Eastman Kodak "Minicard" system of information storage and rapid mechanical retrieval by electronic machines are shown above and below. The Minicard film record, a tiny piece of microfilm about the size of a postage stamp (shown at right same size and enlarged on p. 33), is the "memory" of the system for the storage and retrieval of documentary information. Both the indexing code and the graphic information are contained on this unit record in a single "package." As many as 12 legal-size pages can be recorded on one film record, with enough index area remaining to provide 49 characters of alpha-numeric code.



know her last name.")

Proper indexing obviously is required in any information retrieval system, and the controlling factor determining the most efficient system is the size of the universe.

For comparatively small universes, hand searches are satisfactory. Libraries, using a card catalog of their book collections, can locate pertinent bits of information quickly. The author-subject-title approach to cataloging used in virtually all libraries is comparatively simple.

Under the Dewey decimal classification system, for example, each book in the collection is assigned a number based on its subject. Where the Library of Congress system is used, each book is assigned a combination of letters and numbers, and in alternate systems—Ranganathan, Vatican, and others—signs, symbols, letters, and numbers are employed in combination.

In all cases these designators are based on the subject matter of the book. Books are placed on the shelves in numerical order, and after the book call number has been determined, it is necessary only to go to the shelf on which it is stored.

Subdividing subdivisions

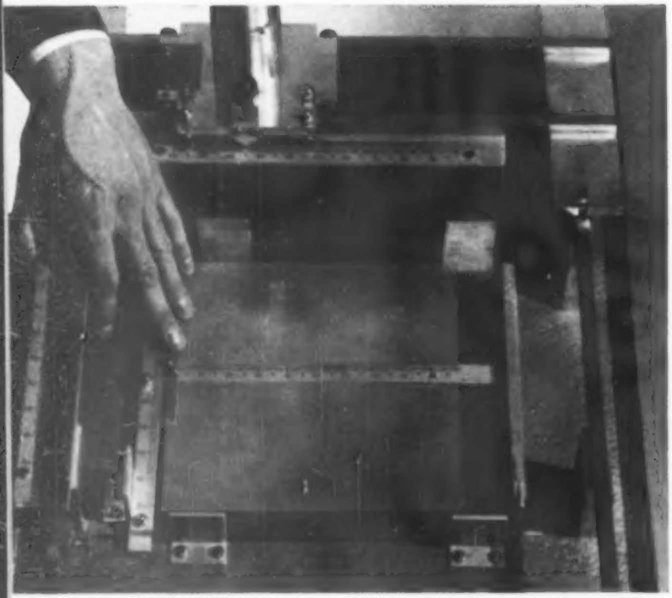
In the Dewey decimal system, for example, all of man's knowledge has been divided into 10 major groups. In turn, each group has been divided into 10 sub-groups which are divided further into 10 sub-sub groups. Similar divisions of the sub-sub groups are carried on almost indefinitely. In the 10 major groups, for instance, 000 to 099 covers general works, 100 to 199 covers philosophy, 200 to 299 religion, and so on.

The pure sciences, between 500 and 599, are subdivided as follows: 510 covers mathematics, 520 astronomy, 530 physics, 540 chemistry, etc.

In turn, mathematics (510) is divided into arithmetic (511), algebra (512), geometry (513), and the like. Geometry (513) then is divided into plane geometry (513.1), curves (513.2), solid geometry (513.3), etc.

In addition to the classification number, the letter of the author's last name is shown. If two books on plane geometry were written by authors named Jones and Smith, Jones' book would be numbered 513.1J and Smith's book would be 513.1S. As books with like numbers are filed alphabetically within that number, either Jones' or Smith's book could be easily located, even though the same number appears on the two books.

When a book is cataloged, several 3" x 5" cards covering that book are prepared. Separate headings are typed on different cards, showing the author's name, title of book, and one or more subjects. Therefore, if a book is concerned with arithmetic, algebra, geometry, trigonometry, and calculus, it logically would be assigned the number 510 (mathematics). Cross index cards, filed alphabetically under "arithmetic," "algebra," "geometry," and other subjects pertaining to the book would be inserted in the card catalog. Since all these cards would bear the same call number, it would be possible to locate the book easily—even if only the author's name, title, or something about the contents were known.



STEEL TEMPLATE COVERS *"keyword" cards in the overhead view of the Jonker Business Machines' "Termatrex-10" trackmodel, above, which serves as the basis of an inverted method of punched-card data handling. When the light is turned on from the machine's base, light dots piercing the cards give the codes or "terms" as designated by the serial numbers of coinciding holes. In this manner, tens of thousands of items can be searched almost simultaneously by any member of the clerical staff.*

Holes and numbers

The Dewey classification pre-supposes that index cards will be filed in alphabetical order. Although it may be advantageous in some cases, alphabetical filing is not necessarily employed in another system which involves notched or punched cards that can be sorted manually. Where the universe is limited to approximately 15,000 items, punched cards can be used effectively.

The McBee Keysort system, for instance, employs holes punched around a card's edges according to a pre-determined code. Thus, desired cards can be separated from others by inserting a needle through the holes. Holes are notched either by a hand punch or by machine. A single or a multi-pronged fork can be used to hand sort the cards, or they can be sorted by a hand-operated device known as a selector.

Limited to about 200 holes which can be punched in the margins of the individual card, the system is inconvenient for recording complex relationships among index entries. This also is true of the Dewey system. Cards may contain abstracts of information sought, bibliographic information, or a document number. In the latter case, numerically filed documents may be located in a document file after the accession number or numbers have been determined.

Number-matching systems

Another type of hand-sorted card is used with the number-matching system known as "Uniterm." Documents are analyzed in terms of subject descriptors, and accession numbers of appropriate documents are indicated on those cards showing the descriptor. The numbers, listed in columns, are matched visually with numbers on other cards.

A variation, known as the "peekaboo" method, also may be used. Cards are superimposed and document numbers detected visually by light passing through coincident holes in the cards. The Jonker "Termatrex" system uses this method.

Unfortunately, the "peekaboo" method results in the generation of false combinations, particularly as the depth of indexing increases. A limiting factor is the quantity of numbers that may be placed on a single card. Document numbers are revealed to the searcher who retrieves them from a file where they have been placed numerically.

Faster retrieval of information, or retrieval from larger universes, is best accomplished with machines. Number-matching and pattern-coincidence systems exist in which operations performed by hand are done by machine. The indexing limitations here are the same as for hand-manipulated cards, as is the number of documents it is possible to index. Delivery of information to the searcher again is a matter of determining document accession numbers that serve as an entree to the document files.

75,000 indexing entries

IBM, Remington-Rand, and others have developed apparatus that enable information searches of up to 75,000 indexing entries. Punched cards are fed into the machine in stacks of up to 500 at a time. A limiting factor is the tolerance of the user, since many runs of cards are required to extract desired information. When the universe gets unduly large, the time needed to make a search becomes correspondingly long, and other searching methods become preferable. However, for reasonably small universes, punched card devices are satisfactory.

When the universe exceeds 75,000 items, tape-reading devices are preferred to other information retrieval systems. These devices use magnetic tape, as in IBM's "700" series and Remington-Rand's Univac series digital computer, or punched paper tape, as with the Western Reserve University Selector.

Tapes are stored on reels and searching is done either electronically or by means of mechanical feelers. Bits of information selected are transferred automatically by the machine to output tapes. In some cases, output tapes identify the desired document by accession numbers; in others they reproduce an abstract of the document.

Photographic retrieval

Photography and microphotography play an important part in several comparatively new information retrieval systems, including "Rapid Selector," "Filmorex," and "Minicard" methods. Minnesota Mining & Manufacturing Co.'s "Filmsort" system combines conventional punched cards with a microfilmed abstract inserted in an aperture in the card. After the card has been located by machine, an abstract can be enlarged and read (or printed photographically) with a conventional microfilm reader-printer.

Other systems involve index-coding of documents, placing the microphoto of the documents on reels, and searching the reels by a machine that reads the code.

Another system involves placing the microphotos on glass plates. Ten thousand document pages can be reproduced on a foot-square plate. A device will pick out any of the 100,000 pages on 10 such plates and produce an enlarged copy in a matter of seconds.

Still another, in which information is placed on magnetized plastic cards that can be searched at a speed of 100 cards a second, is under research.

The devices described, except for those which bring forth abstracts, actually do not retrieve information. Rather, they determine document numbers which are used to locate documents in a numerical file. Perhaps "document retrieval" rather than "information retrieval" should be used to describe those processes.

A self-abstracting computer

Machine retrieval of information directly from documents has been under investigation for some time, and progress has been made with mechanical scanners. H. Peter Luhn, of IBM, has conceived what he calls an "auto-abstracting computer program." The unique computer eliminates all insignificant words, such as "the," "of," "and," the connectives and stems, and then makes a frequency distribution count of remaining words.

The program has a rudimentary Thesaurus built into it to bring together synonyms in the frequency count.

According to this system, the words used most frequently are the most important words in the document. These words become key words, and those sentences with the highest proportion of key words constitute an abstract of the document. If the significance is very high, a single sentence might serve as the entire abstract.

On the other hand, if the meaning is strung out in several sentences, the machine will print out all of these. Difficulties arise when the document being scanned contains graphs, charts, chemical formulas, or mathematical equations.

Other difficulties also arise. For example, how do you determine the number of sentences or key words to be taken from a document to distill its meaning in a useful condensation? A density factor is involved here; one document may say much in a few words, while another may have an equal quantity of pertinent information spread out over many pages. Despite their complexity, all these problems are nearing solution.

Photoelectric reading

Key-punching information onto cards is an expensive process, and photoelectric reading of documents one day will offer a practical solution. One approach now practical is coding information with magnetic ink. Banks now are using this technique with checks and accounting machines that read magnetically coded characters.

It is comparatively simple to effect mechanical reading of documents that have a uniform, predetermined size and shape, with coded characters in a specific place and of uniform size and shape. Difficulties arise when documents are of different sizes and the machine must decipher characters of different types.

Hand-written documents complicate the problem further, since no two people write in quite the same fashion (a real problem for postoffice automation). The problem is not insurmountable, however, and it will be solved eventually.

One advanced information retrieval method which holds great promise is the machine preparation of book and document abstracts as a by-product of typesetting. An estimated 50% of all scientific literature is punched into the 31-channel paper tape that runs automatic linotype machines. This punched paper tape is machine-readable and can be converted to an input for electronic data processing systems.

A vast storehouse of information is on hand today. Unfortunately, much of it is not readily available because it has not been indexed properly. If all future information were to be recorded for simple machine retrieval, a fantastic amount of past information still would have to be examined, edited, indexed, and coded for machine processing.

Files of such depositories of published information as the *Engineering Index*, *Chemical Abstracts*, Armed Services Technical Information Agency, U. S. Patent Office, and the Library of Congress would have to be examined item by item. The work involved is fantastic, but it must be done. Without it, we must repeat past research to determine answers to questions previously asked and answered.

In the long run, repeated research will prove far more expensive and time consuming than indexing man's knowledge for machine retrieval. Great steps already have been made in this direction, and there is every reason to believe the problem will be solved ultimately. ■

Industrial Research will be monthly in C

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THE EDITORS OF INDUSTRIAL RESEARCH proudly announce monthly publication beginning October.

The decision to issue Industrial Research as a monthly followed a series of surveys with readers and technical authorities who write the features of the magazine. As a monthly, Industrial Research will continue to inform technical management of new scientific developments and their profitable applications in all fields of industry and government.

Typical articles to come (see the display of titles at right) even more will be dedicated to providing the necessary communications link between management and science. The new frequency of publication is designed to help Industrial Research better achieve its stated goal: "to reduce the time lag between invention and production."

The transition October issue (incorporating August, September, and October) will be a special edition devoted entirely to Energy Conversion.

The edition will contain definitive state-of-the-art articles on fuel cells, thermionics, thermoelectricity, thermal energy of the sea, direct conversion of solar energy to electricity, gas turbines for propulsion and power, and nuclear reactor propulsion.

New subscriptions to the monthly Industrial Research will cost $7 for one year (12 issues); $12 for two years (24 issues); and $15 for three years (36 issues). Present subscriptions will be extended for the full length of the subscription term at no extra cost. Please use the order forms in the back of the magazine for new or renewal subscriptions.

ctober!

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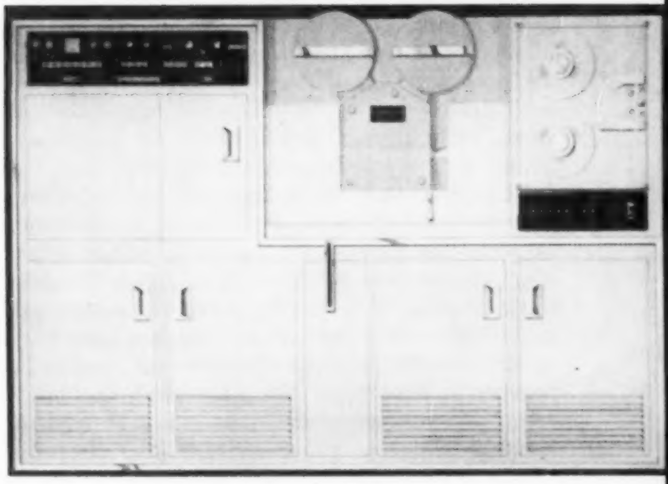
Hot Results from CRYOGENICS

We're against
We're for 'Guardian Angel' Defense Contracts

SEMICONDUCTORS *vs* ELECTRON TUBES

Practical Information Handling

***BITS OF INFORMATION** are taken from magnetic tape, or directly from a computer, and are translated instantly into letters and figures in Recordak's DACOM recording system. The information appears as the finished message on the face of a cathode ray tube. Microfilm records can be made directly, eliminating the need for printing on paper. The new device matches the speed of the computer.*



by **John W. Murdock** *and* **Gustavus B. Simpson Jr.,** *information research, Battelle Memorial Institute*

Soon after joining Battelle in 1951, John Murdock (left) and Gus Simpson (right) were assigned principal roles in designing and establishing government-sponsored scientific information centers. Currently they are responsible for directing research programs in scientific information processing and analysis. Murdock holds BS and MS degrees in physics, while Simpson has a BS in metallurgical engineering. Murdock directs Battelle's library, and Simpson guides information activities and coordinates research.

RETRIEVING INFORMATION poses unnecessary hardships for technical men as they seek a small but specific part of the vast complex of information on a given scientific problem. The qualitative, or area-of-interest, approach thus becomes the most logical of the many ways to set up an information system — including collection, selection, storage, and retrieval. The method suggested in this article actually uses the scientist himself as an information filter, utilizing his own ideas, first thoughts, and established interrelationships to locate the specific information needed.

The technical manager must determine how his organization will attack its particular information problem administratively. The scientist or engineer, the ultimate user of the information, must determine how many of his available hours he can spend profitably with the literature.

Fortunately, the regular user can develop some approach that is reasonably effective for his information problems within practically any information system provided. Each regular user's approach exhibits a unique quality.

The occasional user, on the other hand, must be provided with an information base, but this base should not be so controlled that it penalizes the regular user.

Recognizing the user

Quantitative aspects of the information problem—millions of words, size of storage area, number of items to be retrieved—often suggest to managers and users that mechanization is the answer. A fear is expressed more and more that most engineers are no longer capable of identifying technological implications hidden in the vast flow of information, especially when the implication is part of information outside of their discipline.

The counterpoise to this fear suggests that, if all information is stored in its entirety in a machine, some statistical manipulation of the language will allow the user to retrieve exactly what he needs, when he needs it, and in a minimum of time. This suggestion remains but a hope.

The amount of information to be handled is only a part of the problem; more important is understanding the nature of scientific information and the needs of users. Machines do not solve the problem because, while machines treat statistical and quantitative data, they do not solve the qualitative aspects of the problem. Emphasizing qualitative aspects, we have found that if the user is recognized as an integral part of the information system, the problem of storage and retrieval of scientific information has new but less frightening dimensions.

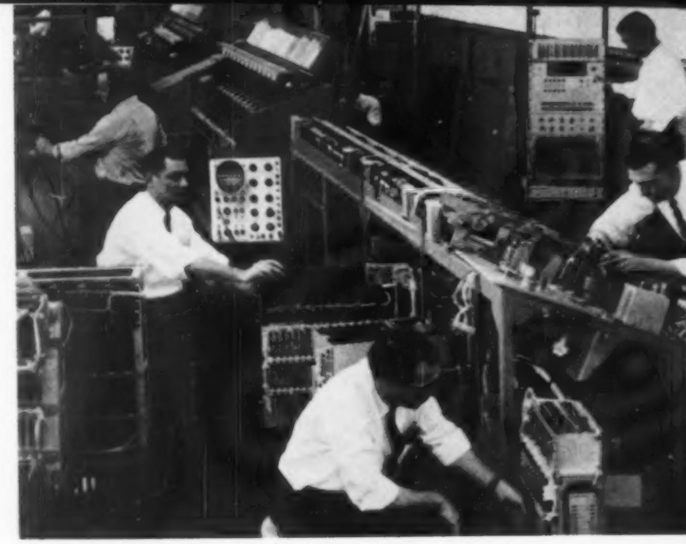
Random search mechanisms

We believe the significant factor to be considered in setting up an information system is that each scientific searcher has his individual approach to information and is stimulated along different retrieval sequences, even in the same field. We have observed that many users think first in terms of the outstanding specialists of the day; others think in terms of outstanding research organizations. These thoughts constitute the users' points of departure.

But when users are *not* aware of people or facilities, their search mechanisms are random because they are unable to define exactly what it is they want to know.

This circumstance, we suspect, will be recognized in time as the very core of the information retrieval problem and will be described as the identification mechanism—a personal, individual action. An effective information system must allow the user to proceed quite naturally and easily from one thought to another, selecting and rejecting information on the basis of the information itself.

Most scientists have an insatiable curiosity which often extends beyond the area of their immediate interest. Quite often information is found in a discipline normally not of interest to the researcher, which may throw a new light on his problems and enable him to advance faster than would be possible otherwise. Allowance must be made for such explorations by providing easy and stimulating access to other parts of the store of information.



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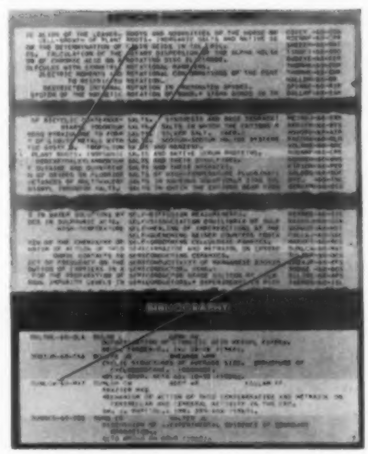


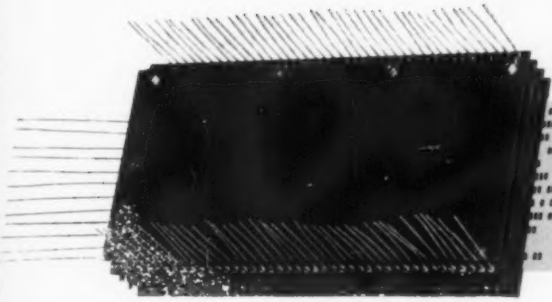
BIBLIOGRAPHY

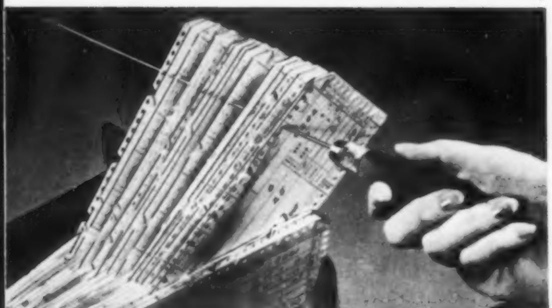
Data or information?

Experience has shown that published scientific material can be grouped either as data or information. A working hypothesis based on this grouping has led to a much sharper definition of the scientific information problem and provides fruitful results for the users. Data are hypothesized to be number or letter patterns, recordings, and drawings which have little meaning unless interpreted. Information is hypothesized to be the recorded, subjective interpretation of data, observations, or other information.

Different techniques are needed to process data and information because data are relatively easy to process by machine, while information is not. This reasoning led us to design information systems which do not use codes. Codes are letter-numeral patterns or, in other words, data.

Storage and retrieval of information by code implies that subjective interpretation can be reduced to data and that a user's information needs or





BURROUGHS, IBM, ROYAL McBEE *all are improving their information storage and retrieval systems:*
1 *Burroughs engineers are working on electronic sorter-readers that process bank documents at speeds up to 1,560 items a minute.*
2 *IBM 704 electronic data processing system automatically prepares keyboard index used in American Chemical Society's* Chemical Titles.
3 *Experimental electronic punched card memory unit designed by IBM uses printed circuit boards for a large capacity read-only memory.*
4 *Manual sorting of pre-punched edge-notched cards is accomplished rapidly with the Royal McBee Keysort system.*

thoughts also can be reduced to a code or data. Actually, successful subject classification of information may never be possible because information, being subjective, means different things to different people.

An optimum information system must provide for the following circumstances:

- The user must guide the selection of inputs.
- Information processing time must be held to a minimum.
- Information, not references to information, must be immediately available.
- The user will not be able to state his information requirements exactly.
- The user must be able to proceed easily from one segment of the system to another.

Meeting of the minds

Battelle's information centers, for example, have been designed to meet these requirements for providing the researcher with information he needs in a form he can use.

Scientists and research engineers of various disciplines screen incoming materials to select inputs into the information system. This step is particularly effective because the user accepts a new responsibility with respect to scientific literature, and his more intimate knowledge of the vagaries of the information serves as a qualitative filter. The filtering function in itself largely overcomes many difficulties generally included in the scientific information problem.

Then an information specialist, receiving guidance (feedback) from the users (technical staff) brackets information judged to be worthy of storing in the information center files. Bracketed information then is extracted by the information specialist who also underlines clue words. A clue word is not a subject as usually envisioned; it is a thought of the user as well as a word that appears in the text.

Clue words are not only technical terms but also names of authors and co-authors, names of organizations where the technical work has been done, or contract numbers if the work was sponsored by the government. The selected material is reproduced from the text onto 5 x 8-inch cards and multiple copies are filed, one of each clue word. There are subdivisions of the files for authors, organizations, and contract numbers, as well as technical clue words.

To retrieve information, the researcher uses the file much as he would an encyclopedia. Some word or words occur naturally to him as he thinks about the problem about which he requires information. He selects the cards filed by any one of these words. Because the word is in context, on the top card, and underlined, his mind immediately is stimulated to accept or reject each entry.

Other lines of approach will be suggested to him because of the additional clue-words underlined, coupled with his innate imagination and initiative. Authors and organizations doing work closest to his interest will be identified, with the information for each identification immediately available. The frustrating circumstance of waiting for the information he desires is eliminated.

Extensive experience with the qualitative approach to scientific information has demonstrated that it is effective in meeting the needs of both occasional and regular users by simplifying and speeding up their information searching task. Such an approach benefits serious seekers of information because the information they use is what they selected and each person's selection is the most precise for him. The occasional user profits from the qualitative approach by virtue of selections made by the regular and more knowledgeable users. The qualitative approach also eliminates unprofitable processing of low-grade information, and avoids many of the problems associated with handling large quantities of information. ▪

by **H. M. Semarne,** *research programing coordinator, Douglas Aircraft Co.*

Language Engineering — *the use of symbolic logic in*

AN URGENT NEED exists for new techniques which will enable clerical help to carry out information storage and retrieval with machines to liberate engineers and scientists for work on technical problems. Among computer techniques developed in recent years to meet this need is the symbolic logic truth-matrix.

To organize the use of recorded knowledge, it obviously is desirable to classify all information to be stored, correlate all facts to guide future decisions, and select recorded information relative to a given problem. The symbolic logic truth-matrix computer technique and other logic methods make it possible to construct decision devices useful in the classification, correlation, and selection of documents, as well as in machine translation of languages.

Development of a large-scale retrieval system will depend largely on classification of concepts rather than of words. Classifying words to organize information is inadequate, because the irrational, natural language of a document is hardly ever the best systematic language for use in a machine. This difficulty is a serious obstacle to accurate correlation of recorded facts and to phrase-by-phrase translation from one natural language to another.

Because natural languages are rather inefficient tools for the symbolic expression of ideas, methods of symbolic logic can be employed to analyze, formulate, and correlate these ideas before they are used, or "hidden among words."

An important consideration in planning an information retrieval system is its adaptability to expansion. Symbolic logic methods ought to provide for the eventual embedding of the present system in one of far greater scope.

The validity of reasoning

Symbolic logic—the study of logic via a formal, abstract symbolism—now is used more and more to investigate the validity of reasoning about statements and classes, including all the non-numerical relationships encountered in natural language.

Some of the uses to which symbolic logic, in one form or another, has been put are: reliability studies of complex systems, logical design of switching circuits, analysis of legal documents, medical diagnosis, and management decision making.

Computers actually aren't as smart as most people believe them to be. Restricted to the binary system, computers can tell the difference only between the numbers zero and one. All numbers first must be encoded in a pattern of zeros and ones before the computer can operate. Thus, in the binary system, the number one is represented as 0001; two as 0010; three, 0011; four, 0100; five, 0101, etc. For our purposes, one represents a "true" element and zero represents a "false" element.

One of the simplest and most useful techniques for proof in symbolic logic is the *truth-matrix*. It is used for definition of basic logic relations, called *functors* (see Venn diagrams, p. 47), as well as for complex *statements* built up from these functors. A truth-matrix is a table of "true" and "false" elements (one and zero in the computer), having as many columns as there are variables, or *propositions*, in the statement, plus one additional *truth-column* holding the result of applying the given relations.

Basic functors are two-propositional, except for "denial" which is merely the negation of one proposition. The rows of the truth-matrix are made up of all combinations that can be formed by writing zeros and ones into the proposition column. For two propositions, there are four rows, namely 00, 01, 10, and 11. In general, the number of rows will be two raised to the power of n, with n being the number of propositions.

It is easy for a computer to generate the rows of a truth-matrix from the all-zeros combination through a binary count up to the all-ones combination just by adding one repeatedly. The computer also can readily compute the "truth" of a given statement for any zeros-and-ones combination of proposition-entries. If the result in the right-hand column is one, then the statement is true; if the result is zero, the statement by implication is false.

As a primitive example of implication (see Venn

diagrams), all row-combinations, except the third, result in ones. If proposition "a" stands for "Mr. Jones is calling his office long-distance," and "b" for "Mr. Jones is out of town," then row three, which says "it is false that 'a' implies 'not-b'," means "if Mr. Jones is calling his office long-distance, this does not imply that he is in town."

The fourth row says "it is true that his calling implies that he is out of town." The first two rows say that, if he is not calling, then this implies that he is either in or out of town. In other words, if he is not calling, there is no conclusion to be drawn.

The result column, 1, 1, 0, 1, is peculiar to the implication functor. Reading downward as a number, the contents of this column will be termed the *characteristic* of the functor (for example, 1101 or, in decimal, 13). Complex statements involving many functors, the way an algebraic expression involves additions or multiplications, also have characteristics. These are the logic keys to a statement.

Another useful way to characterize a statement is to write down the row-numbers corresponding only to asserted rows—rows resulting in ones. For the implication functor, these would be 1, 2, 4. This array of numbers will be called its *assertion pattern*.

In the machine, each basic functor is converted to an algebraic equivalence evaluated by a sub-routine. A logic statement is analyzed by a program which strings together these sub-routines as prescribed by the statement. The resulting assertion pattern can be used in various ways. It can be translated into decisions, simplified to spell out the non-obvious meaning of an involved contract statement, or compared with other stored assertion patterns for information retrieval.

The symbolic approach itself is non-arithmetical. It merely methodizes languages. It features a very flexible matching ability which can be used to analyze concepts. This is in contrast to an approach limited to the logic of collected messages without regard for meaning. Symbolic logic, as indicated here, can do far more than merely catalog the frequencies of musical sounds in the hope of having someone perceive a melody.

Polish prefix notations

To simplify typing and to write down logic statements in a form readily tractable, a linear form attributed to the Polish logician, Lukasiewicz, has been introduced. A list of the Polish symbols corresponding to basic functors is shown in the chart below.

In the Polish prefix notation, not a, or $\bar{a}$, becomes Na; a and b, or a·b, is Kab; and the statement a or b but not c, or (avb) · c, becomes KVabNc. The dot, which represents conjunction, becomes K, and avb, which represents a or b, becomes Vab in Polish symbols. By eliminating parentheses, dots, overlines, and brackets, the typing of statements and the statements themselves are easier to handle and less prone to error.

TABLE OF TWO-PROPOSITIONAL FUNCTORS

POLISH PREFIX NOTATION	[illegible] SYMBOL	MEANING	CHARAC-TERISTIC
Na	$\bar{a}$	not a (denial)	10
Kab	a·b	a and b	0001
Aab	$a \vee b$	a or b (but not both)	0110
Vab	$a \vee b$	a or b (or both)	0111
Pab	$a \downarrow b$	neither a or b	1000
Eab	$a \equiv b$	a like b (equivalent)	1001
Cab	$a \supset b$	if a, then b	1101
Sab	a/b	not both a and b	1110

A point of departure for all documentation research is the traditional library index. The first step results from a need to go from fixed and little expandable subject categories of the library index to flexible categories of information provided by many special libraries today.

In multi-aspect indexing—a method used in the symbolic logic approach—documents are stored under groups of clue-words which characterize their contents. Retrieval is effected by requests made up of any combination of clue-words.

The machine runs into a snare on retrieval. If too many clue-words are combined into one large group, false drops will result from lack of resolution. If, on the other hand, a document is indexed under a

few clue-words only, it may be overlooked on many requests. Much of the advantage of the system over traditional indexing then is lost.

Determination of clue-words is the central quandary of information handling. Many authors have attacked the problem in ingenious ways, and some have moved successfully beyond that state. Symbolic logic offers a way to catch the essentials and sift out redundancies.

The machine contribution is not speed

Machines are firmly linked with the storage, analysis, and retrieval of information. There is little point in attempting to discuss information handling without rapid electronic computers, but it must be realized that the greatest contribution of the machine to this field does not lie in speed, but in the right type of searching.

The method of the search program depends in part on the method of storing the information. From the viewpoint of logic, encoding of information for storage and encoding of search requests can be regarded as the same task. The mechanics of storage assignment and the mechanics of matching clues are the only important points in which they are different.

To write a search request means to write as precise a set of specifications as possible. The burden on the writer of the request can be lightened immensely; he can be enabled to write a great many requests in the time formerly alloted to one request simply by having the machine compose the request for him. This can be done through symbolic logic.

All the essential facts known about a document—title, serial number, origin, year of publication, location in a file, descriptive terms, and its subject content (materials involved, properties observed, processes performed, ambient conditions, applications, etc.)—are listed, regardless of possible redundancies. Each fact or proposition may be linked with some other propositions or with extraneous useful matter concerning the document sought.

A number of statements now may arise: a or else b (Aab), a or b or c or all three (VVabc), a implies c but not b unless d and e are present (KCVNdNeCacCkdeCaKcb), etc. The machine is directed to run through the truth-matrix analysis, and the result is a sequence of 2^n zeros and ones (for n propositions), the characteristic of the statement.

For every "true" or one, a sequence of n bits (for n propositions) denoting the combination of propositional values corresponding to the "true" result, automatically is recorded in memory. A set of these numbers constitutes a complete assertion pattern for the document (on encoding) or a complete description of the search request (on retrieval).

Three levels of document description can be defined: identification of symbols, identification of their order, and identification of their logic. Information concepts can find expression through logic relations among the underlying clue-words. A sample request that illustrates the relationship among clue-words is shown below:

- *Request:* An article in English concerning aircraft or spacecraft, written neither before 1937 nor after 1957; should deal with laboratory tests leading to conclusions on an adhesive used to bond metal to rubber or plastic; the adhesive must not become brittle with age, must not absorb plasticizer from the rubber adherent, and must have a peel-strength of 20 lbs./in.; it must have at least one of these properties — no appreciable solution in fuel and no absorption of solvent.
- *Clue-words:* English, aircraft, spacecraft, 1937, 1957, laboratory, adhesive, metal, rubber, plastic, brittle, plasticizer, peel-strength, fuel, solvent.
- *Proposition-key: The article:* a = it is an article in English; b = it is an article concerning aircraft; c = it is an article concerning spacecraft; d = it is an article written before 1937; e = it is an article written after 1957; f = laboratory tests were run; g = an adhesive was obtained.

The adhesive: h = the adhesive is used to bond metal to rubber; i = the adhesive is used to bond metal to plastic; j = the adhesive may become brittle with age; k = the adhesive may absorb plasticizer from the rubber adherent; l = the adhesive may have a peel-strength of 20 lbs./in; m = the adhesive may have appreciable solution in fuel; n = the adhesive may have absorption of solvent.

- *Symbolic statement:* KKaVbcPdeCfg, and KAhiKKKNjNklSmn. The statement is now truth-matrix analyzed and its results matched.

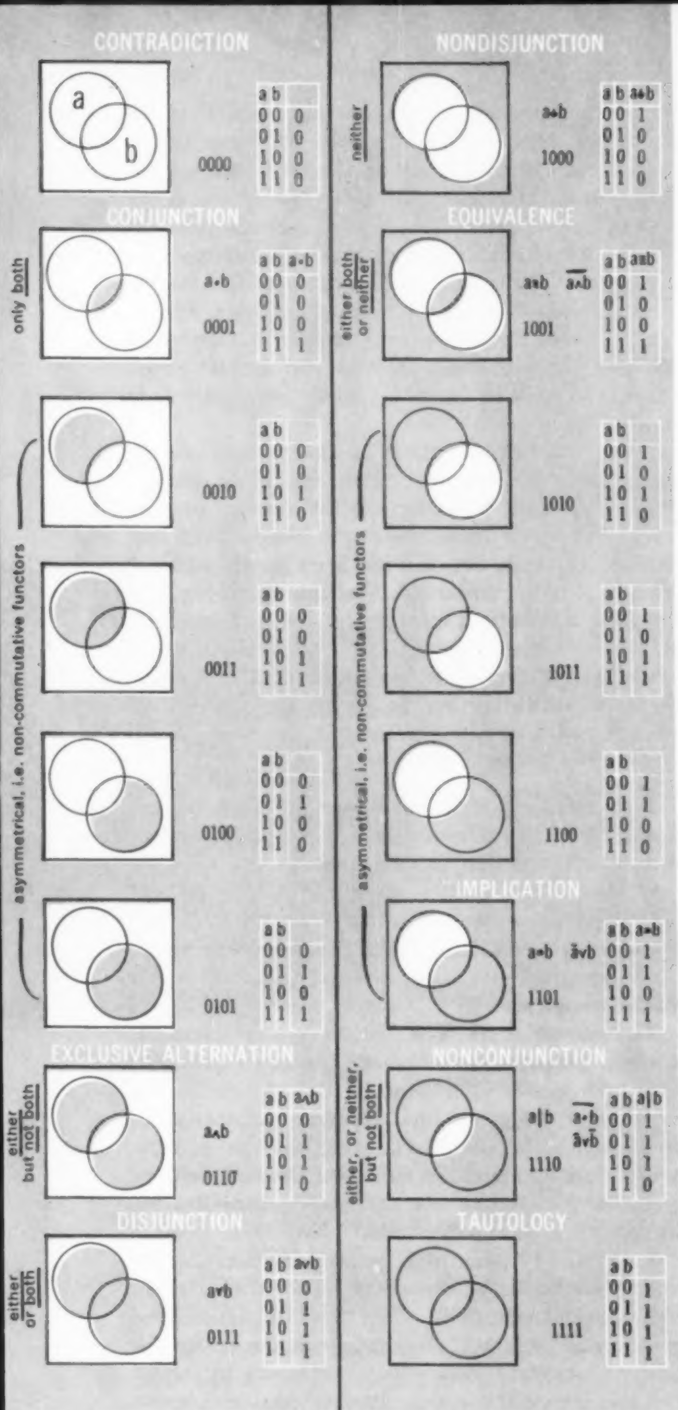
Symbolic logic can be introduced gradually

The tool of symbolic logic can be introduced gradually into problems of information storage and machine searching and translation, while the scope and flexibility of the system developed gradually are increased.

To start, two-propositional functors (functions or variables) and denial are used to analyze the relationships within a body of information and to separate various classes of factors.

Relationships thus brought out might go unnoticed in the confusing form in which a large group of observational data, or a set of statements in a natural language, is usually available.

Group-theoretical relations among the characteristics can be used to simplify statements, especially for making decisions. Tedious operations commonly performed at best by Boolean algebra are paralleled by a numbers-matching technique which makes possible the ordering of otherwise unwieldy clusters of statements. Through this technique, simplification and normalization (transcription in the form using only and, or, not) become automatic.



***VENN DIAGRAMS OF TWO-PROPOSITIONAL FUNCTORS** (left and center columns) illustrate and define the basic logic relations called functors. If two circles represent two variables, then conjunction is represented by the intersection of two circles, and disjunction is represented by the sum of the area of the circles. Contradiction (denial) of one variable, represented by one circle, is the exterior of that circle. Tables at the right of each of Venn diagrams (circles) represent truth tables. The first column in each table is the value of the first variable (1 if true, 0 if false). The second column is the value of the second variable, and the third column is the value of the functor evaluated at the two values of the variables.*

All characteristics of a given number of propositions form a finite commutative group with respect to operation A (exclusive or). By comparing characteristics through the equivalence operation E (1 if alike, 0 otherwise), it is possible to have the machine find those group elements which have the simplest symbol equivalent.

The possibility of probability factors

Many of the decision-making procedures which have been developed from symbolic logic principles can be adapted readily to the calculation of probability factors, instead of bare "yes" and "no" answers. The algebraic equivalents through which logic calculations are done by the computer permit introduction of decimal fractions for probability factors, instead of zero and one alone.

Alternatively, without very much extra effort, weighted multiple retrieval could be effected. For example, each of several documents could be retrieved with an attached order of desirability. It then would be possible to have the machine judge these through a numerical criterion. The operator, on the other hand, may prefer to use his own judgment as to the comparative suitability of his results.

To achieve even more freedom in translating diversified and intricate statements in natural language into machine language, logic predicates and quantifiers could be called in.

Quantifying operators could be introduced as special notes by which to evaluate properly the results of a truth-matrix analysis. Alternatively, for purposes of computation, the quantifiers could be approximated by prearranged threshold values which then would be used like probabilistic weighting factors.

In the machine, dictionary entries are kept out of the way of the characteristics. If part of a document record were devoted to textual material and part to a code, the effective search rate would be cut severely because of the idling of circuitry during passage of the textual part of the record.

The search operation therefore should be broken into two portions—first, matching of the logic form or assertion pattern of the document and proposition code, and second, the special table-lookup in the proposition-key. The second operation, of course, is performed only when the first operation results in a match.

The amount of detail used in describing concepts stored or disclosed in the document file depends on the user's needs and the nature of the application. These factors also would determine whether a one-pass search or an iterative, that is, repeating, procedure should be used. If the file for an area were appreciably less branched in its descriptive terms than the type of request addressed to it, the iterative analysis approach may be more advisable.

In addition to the need for retrieving information, it also is necessary to analyze documents for various purposes. It may be desired, for instance, to examine a collection of data from various sources to deduce the answer to an apparently extraneous question. Or, on receiving or recalling various barely related facts, it may be desired to find a particular document.

Of course, the actual purpose of using "sufficient clues" is the correlation of hints and guesses in hopes of locating a document narrowly described.

Finally, machine translation

In view of the parallel relation between the symbolic logic approach to both document encoding and information retrieval, it is easy to see the further parallel relation between these and machine translation.

Machine translation has received a great deal of attention and many results from various parts of the world have been reported to date. This subject deserves more than a few remarks, especially in view of the need for use of essential scientific data from foreign countries. Only a brief outline of the contribution to machine translation of techniques based on symbolic logic analysis will be given here.

The main tasks in machine translation are: construction of a formal system (including word lists) for describing natural languages; definition and evolution of formulas for translating from one system to another; development of the principles necessary for programing and coding these formulas into the machine.

Symbolic logic as a tool enters into all three tasks, especially the first one. The third task, being the one most closely related to the similar tasks in information searching generally, would respond directly to the symbolic logic treatment discussed above. In other words, the truth-matrix analysis, the characteristic, the group-theoretical relations among characteristics, and the assertion pattern matching technique all are applicable to the handling of data consisting of linguistic formulas.

The second task often is merged and sometimes confused with the first. The confusion happens largely because of the difficulty of divorcing semantics from the compilation of appropriate word lists. The development of the necessary formulas is basically a logic problem. For the source-target language pair, the proper formula structure can be set up by symbolic logic.

There is a danger in becoming so deeply involved in theoretical considerations of a retrieval system as to lose sight of its practical requirements. Why not keep in full view the logical economy with which human beings, such as a good research librarian or a good oral interpreter, work? The dexterity of a specialized human mind in "homing" rapidly toward the search goal must remain the ultimate aim of the documentation researcher, until that aim is reached and can be surpassed by a machine.

Too often an information system is praised because it has a remarkably large file or an astute way of responding to one type of request. For that matter a dove picking out someone's fortune from a large pile of envelopes is also remarkable, if somewhat one-sided. It perhaps is not so much what a human being looks for in searching a library, as what he discards along the way, that should tip off those who wish to direct machines to do as well as human beings.

What the machine must be told is how to perform this "preliminary" narrowing down process which enables it to undertake the search "proper" only after some time-consuming blind man's buff through the logic network has been carried out and irrelevant paths discarded. Machine searching, like machine translation, may be divided best into two stages—the rough search (or rough translation) and the fine search (or fine translation). No exact theoretical dividing line can be given.

The narrowing down process

In a human being, this narrowing down process works by means of two-valued logic, and therefore it must work similarly in the machine. The question now arises:

Can machines designed along well-worn lines, and capable perhaps of expediting the "fine search," be expected to master the real executive-robot tasks of the "rough search?"

The answer is no! The "rough search" demands a chess player's ubiquity and judgment coupled with high speed. This is not likely to be performed adequately for some time to come. In machines, non-arithmetical design concepts with as yet unrealized searching skills will have to be developed first. The "searching selector" at Western Reserve University is an excellent start along these lines.

A system of "logic traps" must be achieved which rapidly discards the classes of topics that are not wanted by answering "yes" or "no" to well-ordered questions. It will not do merely to make up for the lack of adequate binary-logic networks by larger and still larger files and by greater machine speeds.

Often, the aspiration to higher speed obscures the purpose of searching. Of course, the highest possible speeds are desired; machine speed itself is, in part, a result of the improvement of logic search paths. Shortcomings in logic, however, cannot be covered up by fast "slavework" in the machine.

As Dean Shera, of Western Reserve, remarked, "The dim light of the electronic tube has led us ever faster along the wrong path. For it is not in speed, but in capabilities that the great promise of automation lies . . ."

One may note that transistors shed an even dimmer light. ■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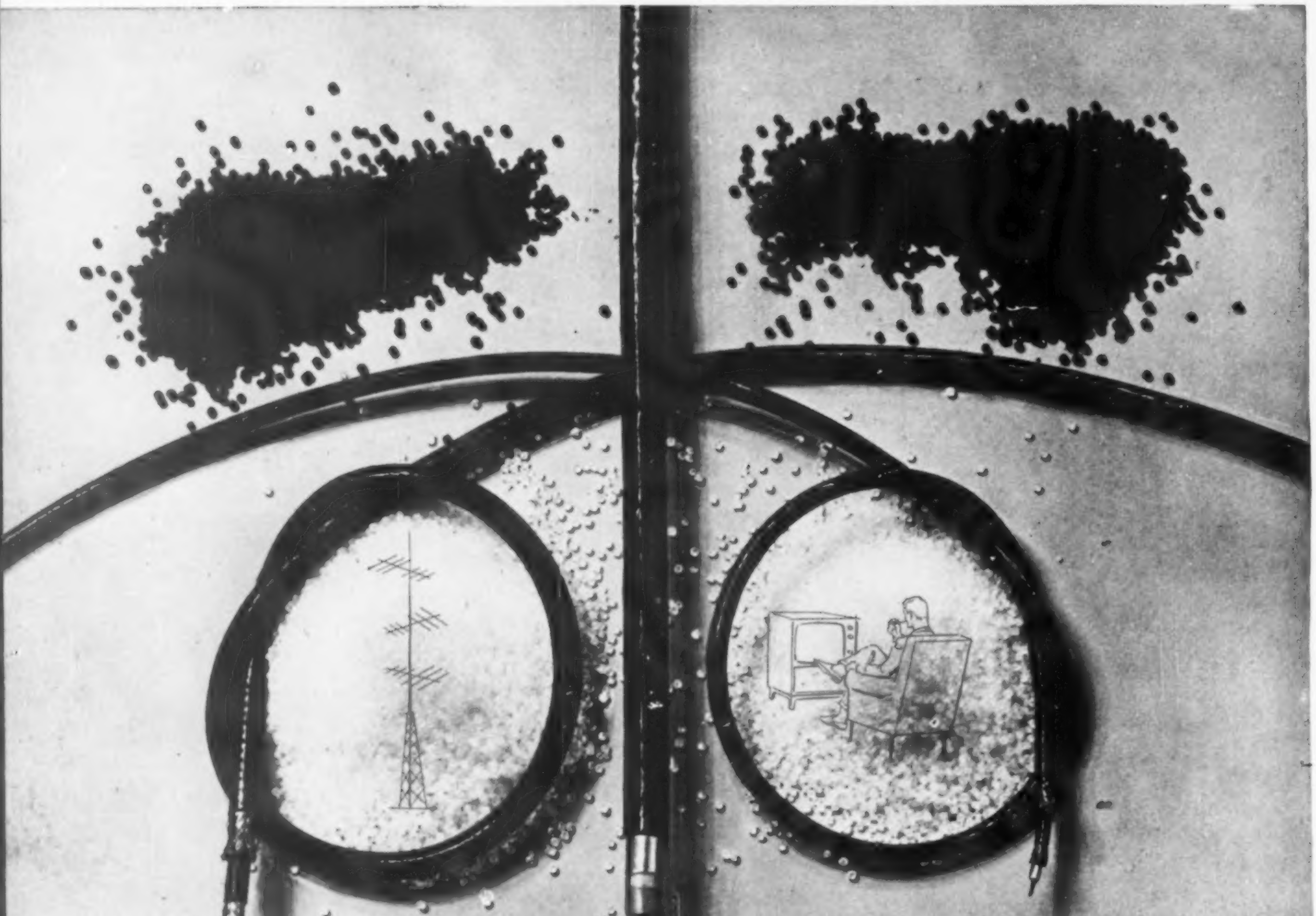


The question below is one that top management of every company looking for 'easier' profits should consider before plunging headlong into diversification.

Why Diversify?

DIVERSIFICATION certainly is one of the more attractive means for improving a company's profit picture. Yet, when a company makes a poor choice for a new product line or an acquisition, the cost is staggering—and a large share of it usually is incurred in the research and engineering departments charged with coming up with the new product line or product refinements.

Unfortunately, today it is difficult to review diversification opportunities in an objective, considered manner. There is an unmistakable aura of romance surrounding diversification—it is the thing to do, a fad. And the increasing complexity of new products makes it even more difficult to judge the future of a new product or assess competitive products or processes.

Why the trend?

Many firms are experiencing increasingly competitive conditions in their own industries and are looking elsewhere for "easier" profits. Problems of rising costs, shrinking markets, and increasing research requirements are all too easy to identify in your own industry, but may not be as apparent in other industries. A strong notion exists in the business world today that "we have all the headaches in this industry—let's diversify into a field where these problems are less severe." The fact that different kinds of problems (but still problems) exist in another field or industry often is not recognized.

The result: service-oriented firms are looking for products, and product manufacturers are adding services. An industrial components manufacturer, for instance, wants a proprietary consumer product; a consumer product company seeks products in a "less hectic" industrial market.

Indicative of this tendency for companies to look for something new to sell—often in each other's backyards—are these *actual* current examples:

- An electronics firm in Boston which has served the military market well for several years now seeks a commercial product. The chief executive's reason: "the military market is getting less profitable—I want something I can advertise and sell nationwide in real volume."
- A research and development firm also in Boston has added an executive charged with finding a product that can be sold to the military market. The president of this firm feels that a profitable, growth market can be found for such a product.
- A Midwest toy maker wants to diversify into electromechanical devices. He is eyeing the commercial electronics market because "I'm tired of heavy competition in the (consumer-oriented) toy industry."
- An automotive supplier has developed many one-shot products for special applications. He wants to find a "mass *consumer* market" for these products or for the know-how they represent.
- A foundry searches for a proprietary product to smooth out the cyclical nature of its business.
- A large metalworking shop acquires a foundry to lessen its reliance on current suppliers and "provide a base for an expanded product line."
- An old-line Eastern paper-making supplier sponsors a fundamental research program in fiber metals. Fiber metallurgy has potential applications in many fields—all completely extraneous to paper making.

by **Robert W. Race,** *supervisor, techno-economics research, Armour Research Foundation*

As a supervisor in the Techno-Economics Research Div. at Armour, Robert W. Race plays an important role in solving decision-making problems of management which require scientific or engineering judgment. He has worked on problems involving market forecasting, plant layout, materials flow, inventory control, and capital budgeting. A 1950 graduate of Denison University, he holds a master's degree in business administration from Northwestern.

A blueprint for planning profitable diversification is available

Do's and don'ts

These days it's difficult to find a business executive who is not seriously considering some form of diversification for his company. Yet, when a company decides to go into a new field or to acquire another firm with different products, it is the research and engineering staff that must develop the product, plan integration of product lines, or learn the technical refinements of an acquired firm's products.

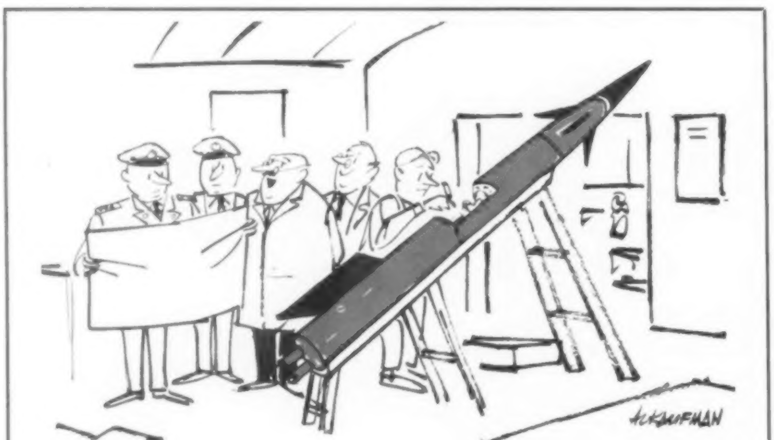
In effect, a company's diversification program creates as great a challenge at the technical level as it does in the treasurer's or the marketing manager's office. With that thought in mind, this article reviews some of the do's and don'ts of diversification planning and the role of the technical researcher involved.

A formal program for uncovering and evaluating diversification opportunities—with full participation of the technical researcher—can avoid many of the emotional considerations, and is more likely to result in profitable diversification decisions.

Of course, the company executive can rely in part on informal tips received over lunch that so-and-so is looking for a buyer for his company, or that a financier is searching for someone to manufacture his client's new product idea. But, the executive who acts solely on this sort of hit-and-miss diversification information is asking for trouble. Too often, the result is a product ill-suited to his company's capabilities, unforeseen investment requirements for new research facilities, costly advertising campaigns, or devastating competition from an unexpected source.

There is no pat formula for establishing a profitable diversification program. Diversification planning takes on a personal element for every company. It is a function of the interests and objectives of the top management of each company. It must be tailored to these interests and objectives.

Certain rules of thumb, however, underlie successful company diversification programs. To illustrate, let's take the actual case of a formal diversification program undertaken by a real company fictitiously named here as the Imaginery Machinery Co. Imaginery Machinery is situated in a city about 100 miles south of Chicago. It has some 2,000 employes engaged in design and production of machinery for the food processing industry. The food machinery industry has been increasingly competitive in recent years, and profit margins have been relatively low. After a six-year plateau in sales volume, management sees diversification as an opportunity for the company to grow and, at the same time, to escape price and service competition in food processing machinery.



"It's a guided missile to intercept the guided missiles the enemy will send up to intercept our first guided missiles."

Step 1: go formal, be objective

As in most other areas of business planning the first step in diversification for Imaginary Machinery Co. was a *formal* determination by the firm's top executives as to what they wanted to accomplish. This step appears to be easy and obvious; actually it was tedious and frustrating.

Such general objectives as "maintain or improve our return on investment percentage" or "be able to use our current engineering know-how" are important, but they do not begin to cover all of the angles. Inherent in every company's operations are limitations in the amount of money available for investment in a new product; management talent available to supervise the development; production and marketing of a new product line; preferences in terms of market conditions; and competition and timing considerations.

Specific objectives — characteristics to be looked for—finally pinned down in a series of exhaustive interviews with company executives at Imaginary Machinery covered customer service requirements, geographical locations of primary markets, manufacturing techniques, patent situations, acquisition possibilities, rate of technological change in the industry, and degree of engineering sophistication in the new product line. These and other objectives were summarized formally and approved in a meeting with top company officials.

Why define the objectives and limitations of diversification interests so early in the game?

First, the subsequent search for opportunities is focused more sharply. Second, criteria for evaluating alternative opportunities (explained below), in effect, become defined. When this is not done at the start of a formal diversification program, the ensuing effort can be emasculated.

Take the case of an electronics hardware producer in Cleveland. This firm decided to make an internal diversification study. However, only a few top management members of this firm felt they wanted to take the time to outline diversification objectives. These executives initially indicated they wanted new products that could be produced with existing manufacturing facilities and sold through current marketing channels.

. . . but it must be tailored to company needs.

Yet, when a study team developed a list of 50 new product ideas which fitted these criteria, the full executive committee of the firm decided the list was too limited in imagination and asked for ideas of a blue-sky or basic research nature (such as pure fluid amplifiers or electron beam machining).

When a new list of ideas was developed and presented, the committee showed interest in several until it learned that the investment required in research, development, production engineering, manufacturing facilities, and marketing for the least costly idea was roughly 20 times what the company could afford.

Viewed in retrospect, this case seems unlikely—yet, the lack of formal, agreed-upon, meaningful objectives has torpedoed many newly-launched diversification programs.

Step 2: determine possible new products

A study team (including a technical researcher) began to survey specific new product ideas for Imaginary Machinery Co., basing its study on the objective listed for the diversification search. Several parallel approaches were used.

One was an industry-by-industry review to uncover those industries which appeared to have characteristics—that is, type of competition, marketing channels, and technological rate of change—most like those being sought by IMC. Once these industries were identified, discussions were held with industry experts—chairmen of special industry committees, government officials, trade periodical editors, and research directors—to identify unmet product needs and product trends in the industry.

Concurrently, a series of interviews were held with independent research scientists who were familiar with the technologies involved—mechanics, metals, and electronics. The study team identified trends and product requirements in the fields of packaging, air-pollution control, ultrasonic machining, containerization, electronic components such as wave guides and solenoids, and hospital supplies. The study team also reviewed new-product literature to trigger ideas related to those embodied in newly introduced products, and, finally, interviewed Imaginary Machinery executives to uncover any ideas they might be harboring.

Surprisingly, two of the ideas finally selected stemmed from suggestions made by a district sales manager and a product engineer—suggestions they had been keeping to themselves until the interview by a study-team member afforded them sufficient opportunity to express themselves.

Step 3: evaluate opportunities

Outcome of the second step was a listing of approximately 20 new product ideas that looked sufficiently attractive to warrant evaluation. As a third step, the study team employed the company's desired objectives to screen out less attractive ideas. These objectives were transposed into evaluation criteria, and information about each criterion was gathered. The table below shows the listing of evaluation criteria or considerations used for Imaginary Machinery Co.

It is important to note the wide range of evaluation considerations used by IMC. Some companies think of this evaluation phase as a market survey. Yet, financial, manufacturing, research, and other factors, many of which are completely independent of market size, all must be weighed in the diversification decision.

One device used by Imaginary Machinery Co. executives to help them conceptually weigh all factors in their decision-making is a matrix with alternative possibilities for diversification listed along a left-hand column. Across the top of the matrix are listed the important factors or criteria to be considered in making the decision.

Some of these factors are current and future market size, type of customers, marketing channels, investment requirements, product development requirements, technology status of industry, patent situation, timing factors, compatibility with current operations, manufacturing techniques required, and possibility of acquisition.

At least two qualitative judgment factors also were included in the analysis: some estimate of success probability for each opportunity,

EVALUATING DIVERSIFICATION OPPORTUNITY

SALES AND MARKETING

- *Nature and degree of competition.*
- *Type of potential customers.*
- *Service, delivery, applications engineering, and other customer requirements.*
- *Estimated size of the market in units and dollars (current and future).*
- *Location of the market.*
- *Channels of distribution customarily used in market.*
- *Promotion and advertising requirements.*
- *Other marketing policies peculiar to industry.*

PRODUCT, RESEARCH AND DEVELOPMENT, MANUFACTURING

- *Nature of product and product line.*
- *Competition from similar or related products (current and anticipated).*
- *Manufacturing techniques and skills required, compatibility with current operations.*
- *Raw material requirements.*
- *Degree of change of technology in the industry.*
- *Requirements for research, developments, engineering functions to support product.*
- *Degree of integration of firms now in industry.*
- *Patent situation and importance of patents.*
- *Extent of government regulation.*

FINANCIAL ASPECTS

- *Investment requirements to enter industry.*
- *Relative importance of manufacturing and other operating costs.*
- *Depreciation practices.*
- *Tax considerations.*
- *Relative profitability of industry and specific companies in it.*
- *Inventory requirements.*

OTHER CRITERIA

- *Managerial capabilities required in industry.*
- *Possibility of acquisition to enter field versus licensing versus product development.*
- *Opportunities for further diversification at later date.*

and an estimate of relative rates of return on investment for each alternative.

In a sense, the matrix approach summarized for IMC executives many of the elements necessary for decision. It outlined the alternatives, pinpointed the estimated outcome of taking each alternative course of action, and provided a probability estimate of achieving the outcome.

One point should be noted here. Obviously, considerable evaluation information was required with the criteria described above. The question arises, how much time and money should be spent in searching out this information? Surprisingly enough, a trained analyst often can dig out the relevant facts and make the necessary analyses in several weeks. In the case of the Imaginary Machinery Co. roughly 35 man-days were spent in obtaining the full range of evaluation information for the 20 product ideas of most interest.

Step 4: plan your action

One important step remains: developing an action plan to guide your diversification efforts. The plan should outline steps necessary to implement decisions reached as a result of the analyses. These steps should be pegged to a time scale so their interrelationships and priorities are definite.

Steps in the plan of action for Imaginary Machinery included product development, acquisition investigation, personnel procurement, another market research study in detail (after product development), manufacturing facility planning, and marketing organization additions.

Diversification planning, whether carried out as described in the preceding pages or in other ways, should not be viewed as a one-time function. Rather, it requires continuous attention and consideration by top management. Further, it can and should be programed systematically to increase likelihood of profitable results. Results of such a program at the real company we have called "Imaginary Machinery" have been highly successful.

However, a diversification program is not the answer for every company in the never-ending battle to maintain and increase profits. It is one way to increase profitability, but it requires an investment in company time and money to analyze the opportunities properly. It must be evaluated on its merits against many, many other avenues for accelerating the progress of a business enterprise. ■

Men must learn to live 200 years

. . . if they wish to master all that today's storehouse of science and technology has to offer.

Today's life span is far too short to gain complete familiarity with all that is known in the physical sciences, mathematics and advanced engineering. Compounding the problem, new discoveries continually appear.

A partial solution is that followed by the AMF Research and Development Divison: encourage a thorough-going collaboration among broad-gauged specialists . . . men who are not only experts in their own fields, but who can appreciate the relationship of other disciplines to their own.

The scope and diversity of problems under attack at AMF require such an interdisciplinary and comprehensive approach. Reflecting the company's wide-ranging interests in serving the world markets of tomorrow, AMF scientists and engineers are probing into a multitude of new and unexplored areas . . . working together to turn imaginative new ideas into new commercial processes and products.

Current investigations range from friction welding to automated production systems . . . water purification to products for leisure time use. New programs may be initiated at any time as the promise of original ideas becomes apparent.

Several senior positions are currently open to accomplished engineers and scientists. Your confidential inquiry is invited. Write to Dr. Kenneth S. Colmen.

RESEARCH & DEVELOPMENT DIVISION

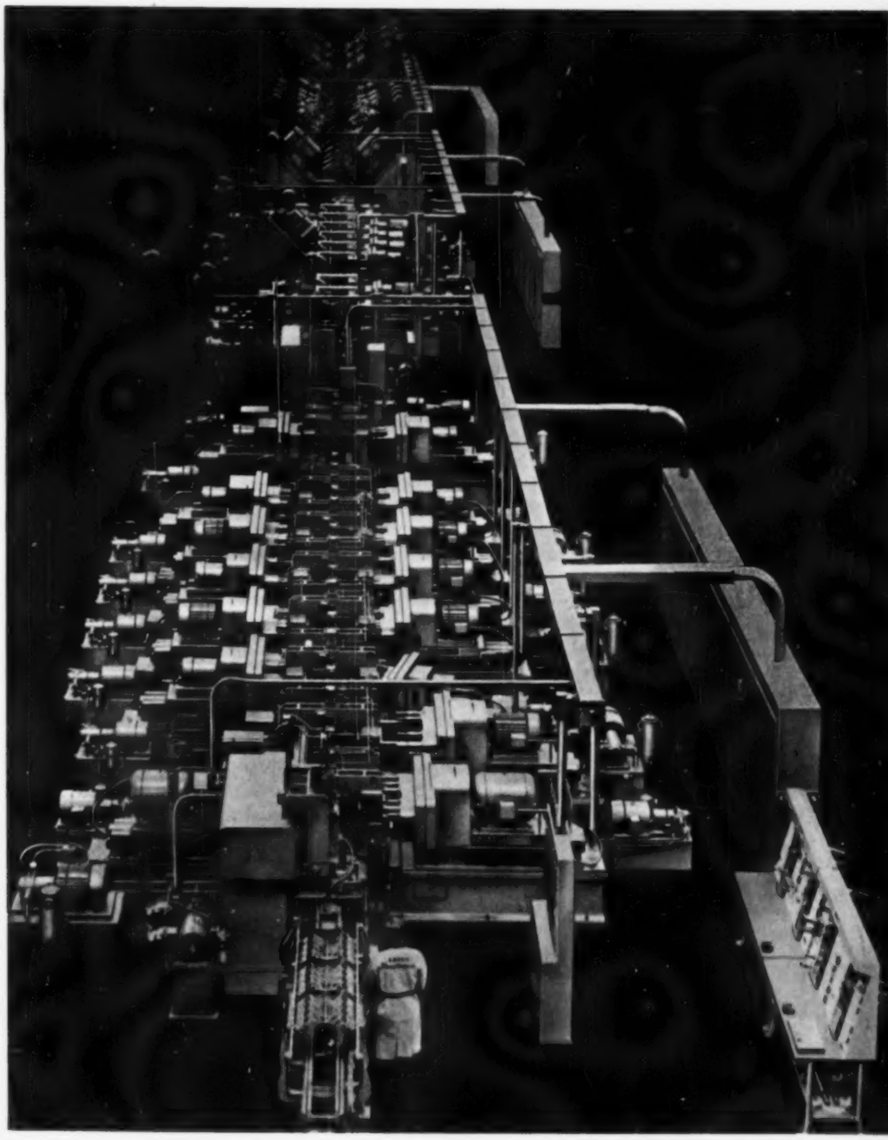
A COMPLEX OF COLLABORATING LABORATORIES: RESEARCH DEPARTMENT; ELECTRONIC DEVELOPMENT LABORATORY; CHEMICAL DEVELOPMENT LABORATORY; MECHANICAL DEVELOPMENT LABORATORY

AMERICAN MACHINE & FOUNDRY COMPANY

689 HOPE STREET, SPRINGDALE, CONNECTICUT

Quiet Revolution in Metalworking

Recent applied research in the metalworking industries has resulted in the first major manufacturing advance since Henry Ford. New hardwares, new methods, new ideas are transforming the plant complex into a single, efficient production tool to spearhead a revolution in the sixties.



by **H. Dale Long,** *president, ASTME, and president, Scully-Jones & Co.*

ENGINE BLOCKS *(in foreground, above) are carried automatically through dozens of successive machining and inspection stations in this overall view of a building-block transfer machine. One operator tends the massive multi-operation machine. When design changes occur, modules do not become obsolete.*

INDUSTRIAL PLANNERS now can create a single integrated production system — a plant that is, in effect, one big highly versatile machine tool, no more difficult to control or understand than the individual machine tool of today.

Yet, despite metalworking's successful response to its many challenges, manufacturing research presently is being carried out on a haphazard basis, and the majority of machine tools in this country are obsolete.

Only a degree of sophistication separates the modern production facility from the classic River Rouge plant of the early twenties. They are still cousins. In both, the machine tool is conceived as merely a

highly specialized working unit of a production line, which is part of a still larger complex including materials handling and assembly operations. The total plant is a labyrinth of departmentalized functions operating under an extensive system of control and coordination.

On the brink of revolution

Several recent industrial challenges have pushed this manufacturing concept to the brink of revolution. With the advent of space technology, the metalworking industry has had to learn how to machine and form superhard alloys efficiently, how to maintain tolerances measured in hundred-thousandths of an inch, and how to assemble products that may have a million components.

These advanced products—supersonic aircraft, missiles and their complex components, even spaceships — must be produced at low cost. The rising percentage of national product represented by military expenditures must be spent so that maximum hardware is produced per dollar. Mere dollar appropriations are meaningless. Actual hardware — not dollars — are needed as a deterrent to war.

Manufacturing technology has grown rapidly to meet these challenges. In the process, a number of dreams have become realities, carrying with them the possibility of a new approach to manufacturing.

Advances that will usher in the new one-machine concept already have been heralded as major technological breakthroughs. In all probability, the fully integrated plant will appear quietly on the industrial scene as the following trends expand, are incorporated, and finally metamorphose existing production facilities.

Commanding tapes

Control of machine tools and manufacturing processes by taped commands is now a fully proved method of upping manufacturing efficiency and cutting production lead time. Completely automatic machine tool operations are possible and economically feasible even with production runs as small as one piece. Numerical control has seen service for several years, but not until 1960 was it generally accepted by industry.

Numerical control systems are of two types: positioning systems and contouring systems. Positioning systems, applicable to precision drilling, grinding, and boring machines, have demonstrated their ability to reduce work time by 80 to 90% in some applications. Their "repeatability," or ability to maintain accuracy during the course of a production run, is inherently superior to manual operation.

Positioning control systems can be programed by manufacturing engineers after only a few hours training. More elaborate contouring control systems, capable of producing two- and three-dimensional profiles on complex parts, normally require computer programing. While most plants do not possess the type of computer needed for this work, a number of numerical control computer centers have opened up. Several aircraft companies, for example, offer to take customer's blueprints, compute a program, and furnish the customer with a control tape ready for machine installation.

Save as you produce

Despite high initial cost ($5,000 and more for positioning systems, and $50,000 and up for contouring systems) manufacturers report savings have paid for complete systems in from six months to three years.

Such savings are not at all unusual, since numerical control boosts efficiency in three critical areas. First, it is common for one numerically controlled machine to outproduce five or six manually operated machines. In the long run, this should reduce capital investment substantially.

Second, the inherent accuracy possible with numerical control definitely cuts reject rates. Third, tooling costs are sharply reduced. Positioning systems dispense with elaborate jigs and fixtures. Contouring systems eliminate the need for costly hand-finished templates which sometimes are 10 to 12 weeks in the making.

Programing required by numerical control systems also has been simplified. With one system, for example, the operator manually machines the first piece of a production run. Machine movements are recorded on tape and subsequent pieces are produced automatically by playing back the tape. (See *Tape Recording Today*, INDUSTRIAL RESEARCH, Vol. 1, No. 1, pp. 63-69.)

A new automatic turret lathe operates on a similar principle, and a simplified contouring system introduced a few months ago can be programed without the use of a computer. It has aroused great interest among those who want to install numerical control, but who do not want to purchase a computer or computer service.

Contouring systems presently receive their largest application in the aircraft and missile industry, where intricate wing and fuselage sections must be machined from solid metal rather than from sheet metal, and where rocket nose cones, precision airfoils, and turbine blades for jet engines must be shaped to precise aerodynamic tapers.

The next major field of application probably will be die sinking (cutting a recess in a die for drop forging, press working, or plastic molding). Several automobile producers are investigating numerically controlled die sinking with a view to expediting production and — even

more important—eliminating costly wood or plastic die models.

Numerical controls provide the key to production versatility in the modern plant. Product and tooling changes in many cases require little more than the changing of programed tapes. Numerically controlled machines enable the manufacturer to record the physical operations of an entire production line.

Consequent reduction of production change-over time would enable companies to store product inventories in filing cabinets rather than warehouses. Critical defense items containing complex machined parts can be given a pilot production run. Tapes then can memorize the machine procedure and store it until an emergency demands full-scale production.

Advanced building blocks

Another metalworking stumbling block, both in production and product design, has been the high cost of rebuilding transfer machines. For years, mass producers of automotive parts and appliances have used fully automatic transfer machines where production volumes run into millions of units.

Transfer machines consist of a long series of machining stations through which parts are conveyed by automation devices. They represent what is sometimes called "fixed-program" automation, as contrasted with "flexible-program" automation possible with numerical control.

Fixed program transfer machines traditionally have been designed for the production of a specific part. When the part design changes, it is necessary to rebuild the machine completely, in some cases at a cost comparable to the construction of a new machine. Thus, manufacturers have hesitated to incorporate radical design improvements in their products, especially when such improvements might make existing fixed program machines obsolete before they were paid for.

During the next few years, most transfer machines will be constructed from "building blocks" or modules. When a product design change occurs, modules do not become obsolete—they simply are rearranged and retooled. The net effect is to cut long-term capital investment costs for mass-production manufacturers and to provide greater flexibility in product design.

Also, medium-run producers who may not have been in a position to use fixed-program automation may find it possible to do so with production lines constructed of standard building blocks. Individual machine tools also are being designed on the building block principle.

Where numerical control provides efficient, flexible machine operation, the building-block principle increases the versatility of the machine itself. A maximum range of possible set-ups and production sequences will be possible at minimum cost and machine inventory.

Because numerical control and the building block concept make manufacturing lines more versatile, they have the effect of making the introduction of advanced products less costly and more rapid. This shortens the lag between the time when research comes up with a new or improved product and when actual production starts.

Also, with the knowledge that currently available manufacturing equipment can turn out radically different types of products with little changeover cost, researchers feel a a new sense of freedom. They can design new products entirely in terms of their functions, rather than having to take the limitations of existing manufacturing lines into account. New products no longer need to be mere "face-lift" versions of older models. Research ideas, no matter how radical, can be turned into reality in a hurry.

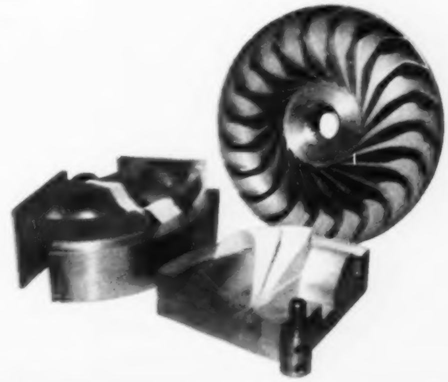
Care and feeding of variables

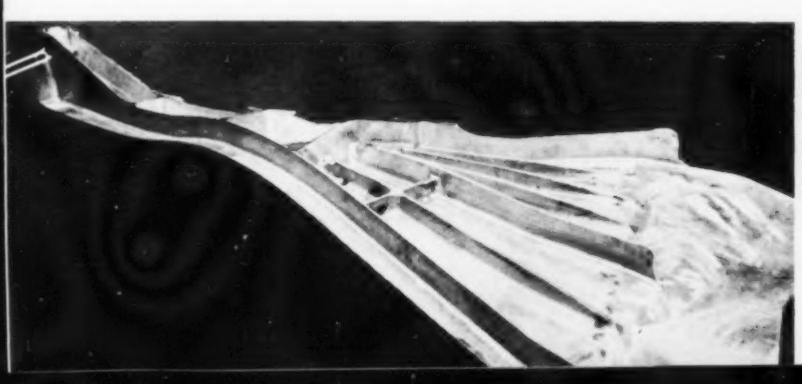
Computers in manufacturing are by no means restricted to programing numerically controlled machine tools. Manufacturing plants literally are responsive to thousands of variables. These can be fed into a computer and evaluated. The output is data that can lead management to timely, well-informed decisions.

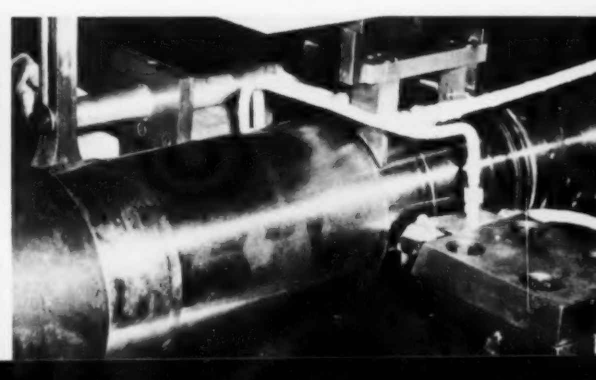
A relatively simple problem for a computer is determining optimum operating conditions. When a plant must produce hundreds of different parts in short runs, for example, a computer can determine the best length and sequence of production runs from the standpoint of operating economy.

A computer system used by one

AMONG THE 'QUIET' CHANGES *occurring in manufacturing techniques are automatic control machines such as Consolidated Controls' Unimate development (at left) which is prodded to desired positions when the operator presses white buttons on the temporary teaching control attached to the hand. The airframe part (below) has been machined from solid metal on a numerically controlled profile milling machine. Prototype of torque converter for an automotive transmission (at right) was designed by a computer. Radio-frequency resistance heating is used to heat – and thus soften – a log of extremely hard material (below, right) during cutting.*







manufacturer determines optimum inventory levels, taking into consideration machine loading, set-up time, and so on. When a part is taken out of inventory, the computer is "informed" and automatically issues work orders for production of new parts as the supply is depleted. A computer thus would remove the danger of parts shortage for a particular assembly and prevent tieing-up capital in inventory.

Debugging production

One company uses computers to plan and design production lines. A mathematical model of the line is developed and translated into computer language to "run" the line. With this method, it is possible to duplicate several months' operation of an actual production line in a few minutes.

Alternative production set-ups can be compared rapidly and the most efficient selected from simulated operating experience. In effect, production lines can be debugged in the planning stages, instead of waiting until machine tools and other production equipment are built and installed. Simulation can save months of delays and thousands of dollars.

Production design offers another intriguing use of computers. Several companies are feeding design parameters into computers that do actual design work on parts such as turbine blades. Output of the computer can be a punched or magnetic tape that controls a machine tool. Prototype models can be designed, tested, machined, and tried out in a matter of days rather than months.

Computers, in a variety of roles, will form the nervous system of the integrated plant of the future. Given basic data, they will plan, integrate, and operate the entire production system. The ability of computers to store enormous amounts of information and to process data in seconds will insure full capacity efficiency in every phase of plant operation.

Since joining Scully-Jones & Co., H. Dale Long has worked in all manufacturing departments of the company and had charge of subcontracting during World War II. He has served as an advisor for the National Management Assn. and was selected as the NMA "Management Man of the Year." He is a member of the R&D Division Planning Council of the American Management Assn., and has led several AMA seminars. Active in the American Society of Tool and Manufacturing Engineers since 1943, he has served as chairman of the Chicago chapter, and has been a national director since 1954. He became ASTME president in 1961.

Putting on the bite

The most advanced monitoring and control devices are useless without the cutting edge, the die, and the electrode that put the "bite" on the workpiece. Manufacturing technology has extended its bite to materials not believed workable a few years ago.

Metalworking processes recently developed will enable any plant to manufacture goods now classified as impractical because of excessive tooling costs. These processes have advanced in a number of ways, partly in answer to the demands of space technology with its exotic metals and partly because of the greater metal-cutting efficiency needed to serve an increasingly competitive market.

Another essential aid to further metalworking progress is now under way—the second of a two-volume metal cutting bibliography compiled by the American Society of Tool & Manufacturing Engineers. The comprehensive bibliography, a record of what has been accomplished, eliminates duplication of costly research and highlights areas where research should be done (See special section on information retrieval, this issue).

Don't pamper machines

Machines now are being run faster than was possible only a few years ago. Reversing previous tendencies to pamper cutting tools for prolonged tool life, manufacturing engineers now seek maximum productivity by running machines at high speeds and feeds. This shortens tool life, but may more than double machine output. Increasing machine output easily pays for the added cost of cutting tools. Use of quickly replaceable "throwaway" cutting tips that do not require excessive machine downtime has accelerated the trend.

Ceramic tools (extremely hard, heat-resistant tools of aluminum oxide) have not had the rapid acceptance expected by some industrial observers. Ceramic tools are inherently capable of better performance than their tungsten carbide counterparts, but their tendency to chip and break has created problems.

Recent experiments at Rodman Laboratory (Army Ordnance Corps) indicate that ceramic tools designed with a new geometry are capable of machining even hardened tool steels without breakdown. Toolholders of sintered metal powders, introduced recently, dampen shock vibrations and may make it possible to use ceramic tools for previously "impossible" applications.

Machining extremely hard materials has become an increasingly common metalworking chore. Consequently, a vast amount of manufacturing research has been expended on the development of totally new cutting processes.

In experiments conducted for the Air Force, Lockheed has shown that superhard materials can be cut at speeds higher than 100,000 feet per minute. The cutting tool, or the workpiece, is propelled by an explosive charge. While this machining method may never become commonplace, it does point the way to a better understanding of cutting tool breakdown and the whole phenomena of metalcutting.

"We hate to send you, Frimly, but you know how expensive those monkeys are!"

Hot and cold machining

Cincinnati Milling is machining superhard materials by preheating the workpiece to about 1000° F, thereby softening the work material sufficiently to make cutting relatively easy. This method will expand greatly as space technology advances.

In Europe, researchers have taken an opposite tack. Reasoning that overheating is the major cause of cutting tool breakdown, they are machining at temperatures below minus 200° F. Fast cutting with good life is possible with the ultra-low temperature method.

Electrolytic machining (removing metal by a deplating action) already is at work in scores of plants where tungsten carbide and other extremely hard materials must be accurately formed or cut. The tool is an electrode shaped to the desired workpiece contour. Since it does not contact the workpiece, abrasive wear is no problem.

Electrospark machining, in which a spark passes between the workpiece and the tool (usually a metal wheel) also is employed extensively in production, especially for tool grinding. Ultrasonic machining has been in use for several years, particularly in cutting hard nonconductive materials such as ceramics.

Holes and slots as small as 0.0008-inch can be cut in the hardest materials by using the electron-beam process, another innovation. An electron gun develops a precisely controlled beam of electrons that can be directed to do work on a target. Target material is heated, melted, or vaporized according to the level of energy density in the beam. The process promises to solve many of the machining problems associated with miniaturized parts.

Explosive forming

Explosive metal forming definitely has taken its place alongside the more conventional forming methods as a useful, low-cost process, especially for shaping intricate parts that formerly had to be machined. In one version, the blank—perhaps a flat piece of titanium—is placed over a die. Die and workpiece are immersed in a tank of water where an explosive charge forces the blank into contact with the die. The water helps to transmit the explosive energy and also cushions some of the shock.

It is possible to form some workpieces explosively that cannot be formed economically in any other way. And explosive forming makes it feasible to do the type of work that normally is done on high-tonnage presses. The process can cut capital investment costs dramatically.

Some explosive formers use dynamite; others work with high voltages, actually discharging what amounts to a lightning bolt under water. Still other methods rely on compressed gases or magnetic forces.

Finishing parts by vibration has

come into prominence during the past year. In this process, parts are mixed with abrasive grains or stones in a tub. When the tub is vibrated (usually at about 2,500 cycles per minute) the abrasive removes burrs, rounds sharp edges, and smooths the part surface, even in recesses and holes where no other mechanical method can reach. The process also is from 10 to 100 times faster than other mechanical finishing methods. Thus many parts now finished manually can be mechanically finished at great savings.

Assembly and inspection

Assembly and inspection systems can benefit from most of the developments already discussed. Automatic assembly systems controlled by tape, designed on the building block principle, and monitored by computers are entirely feasible. The necessary technology exists right now.

Both optical and electronic inspection instruments have advanced towards continuously greater accuracy. Today, a plant can make measurements with an accuracy that would have been unusual in metrology laboratories only a few years ago. Moreover, electrical and electronic sensing devices today are remarkably advanced, as are electrical and hydraulic servos.

These sensitive instruments can be tied into a machine tool to constantly monitor its operations and permit continuous inspection of a part *during* machining. Necessary corrections can be fed back into the control system to stop machining when the correct part size is reached. In this fashion, fully automatic quality control is just as feasible as fully automatic machine operation.

Empiricism or science?

Many obstacles remain in the path of a "louder" revolution in metalworking. Greater emphasis on fundamental manufacturing problems—such as the nature of the metalcutting process—is required, for example. Better coordination of research also is necessary. With a sound understanding of yet undeveloped theory, it would be possible for industry to solve practical manufacturing problems in minimum time, with enormous savings of effort, and without needless repetition.

Traditionally, few scientists have been interested in manufacturing technology. Manufacturing has been regarded as an empirical art, where advances, if any, were made on a trial-and-error basis. Manufacturing engineers have solved countless problems, but rarely have they

known why their solutions work, or for that matter whether the best solutions had been found. The scientific method—the mathematical approach—seldom has been applied in manufacturing.

Today, this attitude is changing rapidly. It has been recognized that no plant or industrial nation can afford trial-and-error search.

When scientific manufacturing research begins to be carried out broadly, we can expect an industrial revolution that will put its historical antecedent to shame.

The price of progress

Another obstacle to a major metalworking revolution is the obsolescence of comparatively new machine tools. Obsolescence is one of the prices of rapid technological advancement, of course. But it also is one of the prices of an unrealistic set of depreciation policies established by the federal government. Companies now are required to write off capital equipment over long periods, rather than the few years indicated by the present rate of obsolescence. *(Attempts currently are being made in Congress to liberalize the depreciation laws by shortening obsolescence time, as most modern nations have done in recent years.)*

In the final analysis, progress depends upon the supply of scientifically trained tool and manufacturing engineers and manufacturing researchers. Few colleges offer an adequate curriculum, and individual companies must train their own engineers. Because of rapid developments in the state of the science, tool and manufacturing engineers are finding it increasingly difficult to keep up-to-date.

Automated equipment requires skilled maintenance. The shortage of trained technicians who can perform this work persists. While Russia is training technicians of this type by the hundreds of thousands, no comparable training program exists in this country. Since the men who keep production lines going are as essential as the men who design them (so far as productivity is concerned), the technician shortage may become more acute than the shortage of trained tool and manufacturing engineers.

Greater cooperation between industry, government and educational institutions is vital if these problems are to be successfully solved. Coupled with a continuing "quiet revolution" in manufacturing technology, such cooperation will secure American industry's world leadership in the production of goods. ■

IR RESEARCH COMMENT *by technical management*

John W. Simpson, vice-president, Westinghouse Electric Corp., before the House astronautics committee:

"Development of a nuclear rocket to operate in conjunction with already planned space programs could increase United States payload capability two to three times.

"A nuclear upper stage to Saturn would double or triple the payloads we can put into orbit prior to 1970. This early capability not only is important during this critical decade in our international affairs but it also will build the base for the period after 1970, when nuclear rockets will dominate space propulsion.

"The nuclear rocket engineer is the key to greater outer space capabilities and represents the biggest single improvement in our rocket capability in this decade."

A report of research scientists at Goodyear Tire & Rubber Co.:

"For every 540 new ideas originating in research laboratories, only one finally results in a useful product. In 1954, seven years were required to move an idea from its birth through the many steps necessary to turn into an end product. This 'test-tube-to-tank-car' transition now requires only five years as a result of increasing new emphasis on research and development activity."

Mort Zimmerman, president, Electron Corp., Ling-Temco Electronics Inc., before Senate communications subcommittee:

"Each state of the union can install 20 educational television stations by matching dollar for dollar federal grants of $1-million per state if Senate Bill 205 is passed.

"A complete educational television station can be installed for $100,000. But, if the sophisticated television systems used by the large commercial stations were installed, each state would get only four stations for its $2-million."

E. V. Huggins, vice-president, Westinghouse Electric Corp., before the American Management Assn., Chicago:

"Companies that do business with the military have only one product to sell—'capability,' the sum total of personnel, tools, and experience with which to do a job. The most important ingredient of capability is 'the idea,' backed up by evidence that it can be successfully put into practice.

"Misguided enthusiasm to take on military work just for the sake of having it in-house can be destructive to both the contractor and to the military. Above all, a company must put its effort where it will do the most good for the country. Benefits to itself will inevitably follow."

Dr. E. R. Britton, director, military engr., Airtronics International Corp., at a Cape Canaveral meeting:

"Tomorrow's interplanetary travelers will be menaced by deadly, manmade 'space garbage' unless a system of celestial sanitation is established soon. The trick will be to design a space vehicle—manned or unmanned—which will go into orbit, ease up to the free-floating pieces of 'space garbage,' and give them a nudge which will send them back into the Earth's atmosphere, where they will burn up harmlessly."

Ray P. Eppert, president, Burroughs Corp., before N. Y. Society of Security Analysts:

"In the current popular concept of the business machines industry, the electronics computer has become 'the tail wagging the dog'.

"Computers have a definite and invaluable place in the processing picture, but results largely will be determined by total system equipments. The computer itself is no stronger than the weakest equipment link in the system chain."

Glenn R. Cowan, management improvement engineer, B. F. Goodrich Co., before Pittsburgh chapter AIIE:

"American industry must enlist the brainpower of all its employes to win the struggle against foreign competition.

"Americans still have the gift of inventiveness that made us a great industrial nation, but modern industry assigns creative work to specialists and often neglects to seek out and develop the ideas of its ordinary managers and workers. Countless thousands of valuable ideas are lost in this way."

Gen. John C. Hull, president, Manufacturing Chemists Assn. Inc., annual construction survey:

"It is significant at this time when there is so much talk about a recession

that chemical manufacturers are going forward with their plans to provide the necessary materials with which to build a stronger economy. It is even more significant that this expansion is going on in the face of declining net earnings in 1960 for chemical manufacturers.

Sen. Hubert H. Humphrey (D., Minn.), chairman, Senate government operations subcommittee, science study:

"This fiscal year, largely in the United States itself, the federal government is spending more than $8-billion for scientific research, development, testing, and evaluation.

"Obviously, the ratio of America's overseas science spending to domestic spending is comparatively small. But it is axiomatic that the total expenditure is inextricably related to and affected by scientific developments abroad, no matter what the source of financial support.

"In the Space-Nuclear Age, international scientific cooperation has grown to a degree unmatched in history. Meanwhile, implications of U.S. overseas science programs to our national security are increasingly significant."

Gen. Georges F. Doriot, president, American Research & Development Corp., before the Investment Analyst Society, Chicago:

"Venture capital has become fashionable. But if it becomes too fashionable it can create its own destruction. Making capital gains the goal, instead of the means of building a strong organization, will result in serious damage.

"Too many companies have over-advertised research and development to their stockholders. They have been hiring engineers at a ridiculous rate just to have them. In a great many companies I have visited, half of the engineering staff does nothing."

Dr. Mario Ottolenghi, vice-president, Novamont Corp., Montecatini Chemicals, before the 44th annual AICE meeting:

"Consumption of petroleum products in Italy increased 73% between 1957 and 1960. This gain is particularly significant since the country did not begin producing petrochemicals until 1950.

"Growth of the Italian plastics industry is out-pacing that of any other country, including the United States and Germany."

An international roster of physicists, before the 1960 International Conference on Physics Education:

"We resolve as follows: In our view, physics is an essential part of the intellectual life of man at the present day . . .

"Physics education no longer can be

considered merely a local issue. Neither can the subject be introduced, full-blown, at an advanced level, but should start at least at the high school level and maintain a close liaison between this earlier stage and those succeeding it.

"We must arrive at a definition of an international teacher of physics, who should be a generator of fruitful exchanges, and who should contribute to breaking down the potential barriers of out-of-date nationalism between our countries, in a century in which the great enterprises of science call for universal collaboration."

John L. Buckley, president, United Technology Corp., American Society for Industrial Security survey:

"Poor security practices are costing American companies hundreds of millions of dollars annually in losses through pilferage, in the employment of undesirables predestined to failure on the job, in the loss of company secrets and invaluable know-how—and in numerous other ways.

"The use of modern training methods and mobile equipment have attracted alert and career-minded young men to the profession which once depended exclusively on untrained gatemen, night watchmen, and floorwalkers."

A survey conducted for the AEC by the American Municipal Assn.:

"Local governments, as well as the state, are already active in the new atomic energy field, in line with their long-established responsibility to seek community benefits through industrial and economic development, and to provide protection for the public against potential hazards. Thus they already are sharing a responsibility with the federal government.

"In the future, local communities will have an even greater share of responsibility. It hardly will be possible to expand peaceful applications and ensure human safety without full collaboration and assistance of local government agencies that are closest to the point of community impact."

The Missile Industry—In Defense and the Exploration of Space, by The Martin Co. executives:

"The prime responsibility of America's competitive defense industry is to widen the U.S. technological lead over Russia. The key to widening the U.S. technological lead lies in 'keeping a revolution ahead' in planning—envisioning the future's potential, so government can choose the best and most feasible items for strengthening the American position.

"We have learned that scientific capability knows no borders, that there is

New IBM Research Center, Yorktown Heights, N. Y.

New Union Carbide Laboratory, Eastview, N. Y.

Republic Aviation Research Center, Farmingdale, N. Y.

G.E.'s Advanced Electronics Center, Ithaca, N. Y.

Atomic Research Center, Rensselaer Poly., Troy, N. Y.

Industrial Research . . . is big business in New York State . . . and growing

In the years immediately ahead, New York State's more than 1,000 research facilities not only will grow in number, but will step up their rate of growth . . . in atomic energy, electronics, chemistry, automation, missilry and space exploration, communications, product development, and education. The multi-million-dollar research centers shown above are but five examples of the vigorous growth now going on in the state. ■ To further implement the growth of research in New York State, Governor Nelson Rockefeller recently created the State Advisory Council for the Advancement of Research and Development . . . (1) to provide a working forum for the exchange of ideas between laboratories and industry; (2) to attract out-of-state research organizations; (3) to recommend steps the state can take to expand its already substantial contributions to industrial progress. ■ Outline your specific requirements and write for detailed information to Keith S. McHugh, Commissioner, Dept. of Commerce, Room 853, 112 State St., Albany, N. Y. Or phone HObart 2-7511.

NEW YORK STATE

no divine right of technology. Secrets of nature accessible to us are accessible to others. Consequently, there can be no slackening in the energy we devote to probing and anticipating what lies beyond the periphery of today's knowledge.

Dr. Glenn T. Seaborg, chairman, U.S. Atomic Energy Comm., at Science Talent Search awards dinner:

"There is plenty of interesting and exciting work to be done by well-trained scientists who may not happen to be Enrico Fermis or John von Neumanns. In fact, much of the effectiveness of great men like them is due to the many lesser scientists who tried out their suggestions, investigated their findings, or produced new data for them to consider."

Crawford H. Greenewalt, president, Du Pont Co., in an address at Princeton University:

"The problem of conformity is not solely one of protection for the individual—it is in some respects one which involves protecting the organization itself from stagnation created by those who find that 'conformity,' like vice, first can be endured, and finally embraced.

"The unhappy fact is that conformity is for some an alluring state, a condition representing the course of least resistance. All too many, I am afraid, reach a point at which they seek refuge in protective coloring, with security replacing accomplishment as the primary goal.

"When this happens, instead of the individual becoming the victim of pressures within the organization, it is the organization that falls prey to organization men."

Erwin Hiebert, science historian, University of Wisconsin, in his book, "The Impact of Atomic Energy:"

"It was once commonly thought that scientists did not and should not have much part to play in deciding how scientific discoveries were to be used. Today scientists no longer adhere to that kind of isolationism.

"Some of the most capable scientists in our country, when placed into official positions of great responsibility, have experienced that their personal views either were markedly altered when they got down to the difficult business of dealing with the Soviet Union or else they have discovered that some of the most desired and worthy long-range objectives could not be carried through realistically without the most radical compromise." ■

IR CHECKLIST FOR MORE INFORMATION

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☐ OPTICAL GAS MASERS which continuously generate coherent light waves and foreshadow a new medium for communications are now under investigation. Additional information is available from Dept. IR, Bell Telephone Laboratories Inc., 463 West St., New York 14.

☐ OSCILLOSCOPE FOR RECORDING nonrepetitive, high-speed phenomena up to the KMC region and slightly beyond is now available for applications requiring a photographic record of one-shot occurrences. Write to P. O. Box 500, Tektronix Inc., Beaverton, Ore.

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☐ MINIATURE RECORDERS with advanced movement design provide big system features with space and weight saving conveniences. Write for catalog to Princeton Div., Curtis Wright Corp., Princeton, N.J.

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☐ NON-TARNISHING RHODIUM plated on nickel increases life of switch contact surfaces of printed circuits going into computers, guidance devices, and advanced instrumentation, investigation has proved. Information on application of six platinum metals and their alloys is available from Dept. IR, INCO Platinum Metals Div., The International Nickel Co. Inc., 67 Wall St., New York 5.

☐ CAR PERFORMANCE can be improved through the use of Butyl rubber in parts such as weatherstripping, body mounts, engine mounts, radiator hose, and accelerator pedals. For application information, write to Department IR, Enjay Chemical Co., 17360 W. Eight Mile Rd., Southfield, Mich.

☐ UNLIMITED ENGINEERING FEATS can be performed with Aroclors which are available in many physical forms for use as heat-transfer mediums, coolant-dielectrics, impregnants, insulating sealants, lubricants, expansion mediums, and many other tasks. For a descriptive booklet, write to Dept. 4431B, Monsanto Chemical Co., Organic Chemicals Div., St. Louis 66.

☐ APPLIED RESEARCH FACILITIES are available in Massachusetts to firms interested in a stimulating research climate and seeking resources of skill and talent. Information on the facilities is available by writing to Massachusetts Dept. of Commerce, 150 Causeway St., Boston.

☐ DESIGN IMPROVEMENTS to provide durability and trouble-free operation of parts are possible through the use of Silastic silicone rubber, because of its immunity to high temperatures and extreme cold. For information, write to Dept. 4416, Dow Corning Corp., Midland, Mich.

☐ GROWTH OF RESEARCH is being implemented by New York State through the creation of a State Advisory Council for the Advancement of Research and Development. Additional information is available by writing to Keith S. McHugh, Comm., Dept. of Commerce, 112 State St., Albany, N.Y.

☐ SUPERALLOYS FOR JET ENGINE PARTS as well as ordinary steel can be protected against wear, oxidation, and corrosion with Chromallizing processes. Write for illustrated Bulletin RC, Chromalloy Corp., 169 Western Hgwy., West Nyack, N.Y.

☐ PRECISION ETCHING TECHNIQUES are used to solve problems in the fabrication of thin metal parts in any quantity. For details, write to Dept. IR, Mowbray Co., 23 Peck St., Providence, R.I.

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(continued on page 74)

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(continued from page 72)

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☐ SOLID STATE PHYSICISTS, production research engineers, and research engineers are being sought for advanced programs. Send resumé to R. K. Patterson, Dept. HH-4, Remington Rand Univac, Univac Park, St. Paul 16, Minn. ■

ADVISORY BOARD

(continued from page 17)

forces of the atomic nucleus, atomic fission, seismic wave studies of the earth's crust and mountain ranges, radio astronomy, and image tubes for large telescopes.

He is the recipient of nine prizes and awards, including the Presidential Medal for Merit, Commander of the Order of the British Empire, and the John Scott Award. A member of the Advisory Panel on Radio Astronomy, National Science Foundation, he has held academic positions at Princeton and Johns Hopkins.

■ Sir Robert Watson-Watt, governing director, Sir Robert Watson-Watt and Partners Ltd., and inventor of radar.

A consultant in nucleonics, chemistry, and electronics, Sir Robert's inventions include color filters for pilot balloon wind-finding, extending height, and distant ranges; instantaneous visual radio direction finder (cathode ray direction finder) used to locate thunderstorms between 10 and 5,000 miles; high frequency direction finder; and operations research.

He also coined the name "ionosphere" now in universal usage.

Watson-Watt has held a number of important scientific posts in the British government and has been awarded the U.S. Medal of Merit, the Hughes Medal of the Royal Society of London, the Valdemar Poulsen Medal of the Danish Academy, and the Elliott Cresson Medal of the Franklin Institute. He is the author of four books and is currently on a world tour to collect material for his fifth book.

■ Dr. Clyde E. Williams, president, Clyde Williams & Co., and former president, Battelle Memorial Institute.

Internationally known as a research administrator, Dr. Williams has organized and headed research and development programs in numerous phases of science and technology. He received the Presidential Citation for his mobilization of the United States' metallurgical research efforts during World War II, and holds five honorary doctorates from leading universities.

Dr. Williams is, among other things, technical director and board member, Howe Sound Co.; director and executive committee member, Fansteel Metallurgical Corp.; vice-president and director, Borne Chemical Co.; president and director, Clyde Williams Investment Management Co.; director and member, finance committee, the Philadelphia Fund; and director of Ohio Semiconductors Inc., the RAND Corp., F. W. Bell Inc., The Claycraft Co., and the Capital City Manufacturing Co.

■ Dr. Vladimir K. Zworykin, honorary vice-president, Radio Corp. of America, the father of practical television.

Dr. Zworykin's conception of the first practical tube for picture transmission, the iconoscope, and development of the kinescope picture tube, formed the basis for all important later advances in the field of television.

Dr. Zworykin holds more than 100 patents on developments ranging from gunnery controls to electrically controlled missiles and automobiles.

Since his retirement as vice-president and technical consultant of RCA Laboratories, Dr. Zworykin has assumed the direction of a medical electronics center at the Rockefeller Institute of New York. In recognition of his important contributions, he has been awarded numerous medals and honors both in the United States and abroad. ■

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